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BIRDS AND BRITISH FORESTRY[1]

BY WILLIAM LING TAYLOR

INTRODUCTION.

LITTLE is known of the wild birds of Britain in relation to the economies of forestry, and of their status as insect eaters, seed eaters, and distributors, and bud, bark, and timber destroyers. Continental and American foresters, particularly in Germany, Czecho Slovakia, Hungary, and the United States, have paid more attention to the subject, but ornithology in regard to forestry in Great Britain is almost a virgin field for observation and research. The standard forestry text-books, and most of those on forest entomology deal cavalierly with the subject, and the few birds mentioned are classified somewhat arbitrarily into harmful and beneficial species. Careful research into the bird life of the forest, unbiased by prejudice and sentiment, is certainly overdue, because there can be no reasonable doubt that birds play a more important part in forest conservation than has hitherto been ascribed to them.

In the first place, available knowledge of the dietary and habits of our wild birds is fragmentary. Secondly, what is, for want of a better term, known as the balance of nature has long been hopelessly upset in Great Britain, and forest officers are confronted in any problem of natural history with conditions which can only be described as mainly artificial. Thus an inherently intricate problem is hampered by lack of data and immensely complicated from the start. The destruction of natural forest and the later formation of woods artificially; the rise and partial decline of agriculture with their effect upon land drainage, cropping, and the growth of weeds; the spread of population; game preservation and the Bird Protection Acts are the principal factors in the present position, and if forestry is to benefit an endeavour will have to be made to encourage and aid the distribution of the various species of wild birds, as far as possible, in numbers proportionate to their natural requirements and to their utility. It is upon the question of utility that we are still so inadequately informed.

It is indeed doubtful if any bird can actually be classed as wholly harmful to forestry, and so far as our present knowledge takes us the only species to which no good action can be adduced, within the forest or without, is the wild pigeon. Local distribution is a consideration, and birds that are beneficial in 'normal' associations can be harmful in their reactions upon the general community of forest life if any species is present in excessive numbers or if their usual sources of food supply have been upset. The sparrow-hawk, crow, magpie, and jay are cases in point, as also is the roosting starling.

Broad-leaved and mixed woods provide the optimum conditions for bird life. Conifer woods (5), where not dry or exposed, are favourable to a more

[1] Delivered as the Presidential Address at the Annual Meeting, 6 May 1938.

limited number of varieties, but the species adapted to life in dry conifer woods are still fewer in number, though not in the number of the individuals the woods will hold. There are marked seasonal differences in bird populations because many of our British birds are migrants; there are also seasonal differences in diet, and this is important (4). Dr. Karl Mansfeld (12) of the Thuringian Research Station for Bird Protection at Seebach expresses the view that birds are of particular importance in the destruction of insects in all mixed deciduous woods, also in woods of spruce and fir where these are not on dry ground. He does not, however, consider birds to be of so much importance in combating insect pests in pure conifer woods as there are too few kinds and their range of activity is too narrow. This statement, however, appears to be too sweeping having regard to the striking instances of the efficient utilization of birds reported from Seebach and elsewhere, and, in general, it may also be more true of continental conditions than those in Britain. A recent mass attack of the Beech Roller Moth (*Dascychira pudibunda*) in the Hainisch forest to the north of Eisenach (14), where for three successive years complete defoliation took place, was checked at the edge of Seebach Wood (an established bird sanctuary) in which only a few of the border trees showed recognizable traces of caterpillar damage. A strong flight of the moths to the southwards across Seebach Wood occurred in the following May, and the tits, nuthatches, flycatchers, starlings, &c., were observed to be killing the insects in very large numbers. As infestation proceeded, it was demonstrated beyond doubt that Seebach Wood, in the middle of a wide area of attack, had remained untouched by the pest. Experiments in the control of insect pests in pine forest have been proceeding since 1927 in the Langhagen Division near Neustrelitz in collaboration with the Seebach Station (7). In the case of the Pine Moth (*Bupalus piniaria*) in 1928 and 1929 sample counts in the protected area gave an average of 50 caterpillars per tree, while in the unprotected 'control' area the approximate average was 5,000 caterpillars; defoliation and brown needles were general in the heavily infested areas, while the trees in the protected block remained green (14). The attack was arrested at 30 to 50 metres from the last row of nesting-boxes in the protected block. This particular infestation stopped in 1930 and the continuity of the experiment was broken, but forest officers who visited the district at the time arrived at the conclusion that it had been possible to protect pine plantations by colonization with insect-eating birds. The attack of the Large Larch Sawfly (*Nematus ericksoni*), which developed in the Lake District in the first decade of the present century, gave definite indication of the value of birds in forest protection (9). It was observed that the tits and chaffinches fed extensively upon the larvae, and that great destruction of larvae and pupae was effected by rooks, jackdaws, and starlings, which were to be seen in large flocks in and about the more seriously attacked plantations during the period of infestation.

The classification of birds according to their economic importance in forestry has been attempted a number of times; the compilation of such lists bristles with difficulties, and so inconclusive is our present information that

the task can only be considered an invidious one, except for species accepted by common consent as highly beneficial, such for instance as the titmice and the owls. The considerations are those of diet, habit, and distribution.

THE DIET OF BIRDS.

At first glance a classification into seed-eaters or insect-eaters looks an easy one. It is not so, however, because all but a few species normally indulge in a bill of fare that varies according to the local food supply and is particularly subject to seasonal change. Most of the smaller seed-eaters (e.g. the finches, &c.) nourish their nestlings exclusively on insect fare; practically all birds except the *Columbidae* feed their young on an animal diet, and it is known that nestlings will consume more than their own weight of food per day in the first few days of their lives. Collinge (4) gives the following dietaries for the breeding period:

Species.	*Insect food.*	*Other animal matter.*	*Vegetable matter.*
	Per cent.	*Per cent.*	*Per cent.*
Starling	90·5	6·5	3·0
House sparrow	90·0	5·5	4·5
Linnet	100·0	..	..
Skylark	100·0	..	..
Chaffinch	100·0	..	..
Great tit	90·0	10·0	..
Blue tit	100·0	..	..
Yellowhammer	100·0	..	..
Thrush	96·0	3·0	1·0
Missel-thrush	74·0	26·0	..
Blackbird	60·0	40·0	..
Wren	100·0	..	..

The food of the raptorial birds is chiefly mammalian although the buzzard, kestrel, and most of the smaller hawks and also the owls include insects in their dietary. The services of these birds to forestry are too obvious to be debatable. According to Collinge (4), our native owls all include from 68·5 per cent. to 82·5 per cent. of mice and voles (not including shrews) in their normal diet, and the little owl, an introduced and much vilified species, eats 49 per cent. of insects (including 10 per cent. of weevils) in a diet that is subject to much seasonal variation. The sweeping statements made and believed about the damage done by the little owl have had little justification in fact, as is shown by the recently published Report of the British Trust for Ornithology (1) on the food of this species. The kestrel consumes 64·5 per cent. of mice and voles and 16·5 per cent. of injurious insects, and even the sparrow-hawk which can be harmful in excessive numbers eats 15 per cent. of insects classed as injurious. The same authority (4) gives the food of the woodpeckers as 75 per cent. injurious insects and 20 per cent. ants. The American observers, Beal and McAtee, quoted by Collinge (4), place the woodpeckers in the front rank of

birds furthering the welfare of trees, and Beal's paper was based on the examination of 3,453 stomachs. The cuckoo and the nightjar are birds which frequent both broad-leaved and conifer forests. They live almost wholly if not entirely on insects, and the former is the principal avian enemy of the hairy caterpillar (3). Their diet includes most of the harmful Lepidoptera and some of the Coleoptera, and Collinge (4) records of the nightjar, that 'in one bird shot in the early morning in July, 15 June chafers, 67 garden swift moths, 40 turnip dart moths and 8 great yellow underwings were present in the stomach'. Starlings have been observed in the month of July in Nagshead Nursery in the Forest of Dean busily eating the garden chafer, *Phyllopertha horticola*. It is true that birds may be harmful in one part of the country and helpful in others (i.e. local habit), and that birds that injure agriculture may favour forestry.

The tree creeper, swallow, martin, and the swift have been condemned as eaters of the Coccinellidae (15), but more requires to be known of the full range of their insect dietary. One striking result arising from the examination of a number of stomachs of insect-eaters is the extraordinarily small proportion of beneficial insects and predators that are eaten (4). Pigeons eat a vegetable diet and consume oak and beech mast voraciously. Of the game birds the pheasant eats acorns and beech mast in quantity, but is also an insect eater (4, 15) and is, on balance, harmless in the forest, though not in the forest nursery in springtime. The partridge is not a woodland bird, nor is the red grouse, except that it occurs in and about young moorland plantations and eats some 14 per cent. of insect food (recorded as including *Hylobius abietis*) (4); the black grouse (blackgame) can be troublesome in the younger conifer plantations owing to its predilection for pine and other conifer buds, and the capercailzie is also a nuisance as an eater of buds and shoots if present in numbers, although no one wants this handsome bird to disappear again from Scottish conifer forests.

HABITS OF BIRDS.

Bird habits centre around their migrations, modes of livelihood, and the breeding season. Instinct and bird psychology also enter into the problem (11). The migration of birds is now the subject of world-wide study, and knowledge is advancing. Their modes of livelihood are matters of the quest for food and nesting-places; variations in the normal food supply at once react on numbers and behaviour. The disastrous severity of the winter of 1916–17 will be remembered by British ornithologists for the enormous losses in our population of small birds. Some species are localized for no very apparent reason, such as the crested tit, the principal habitat of which is the Morayshire and Inverness-shire pine forests (10, 16, 17). Hawks and owls occasionally take to bad habits and kill more small birds than is usual. The killer of the woods is the sparrow-hawk; at the same time it accounts for pigeons and a large number of blackbirds, the first of which are useless and the second of no conspicuous utility to the forester. The crow and the jackdaw have acquired evil reputations as

destroyers of eggs, as also have the magpie and jay. We need to know more of these species and ought not to judge them by the behaviour of individuals. Woodpeckers have been condemned for the mechanical damage they do to wood and bark (6), but observation supports the view that their work only damages sound timber on the rarest of occasions; the nuthatch also does occasional damage to bark. It is to be borne in mind that the damage wrought by birds in the woods is often more apparent than real, and that the good they do is seldom so noticeable to the eye. Roosting starlings play havoc in the places chosen by their incredibly large autumnal congregations for the season's roosts; it is fortunate that starlings' breeding quarters bear no relation at all to these communal winter roosting-places which are chosen quite independently, and that at nesting time, when this bird is so industrious an insectivore (4), it can be encouraged in the woods without fear of adverse consequences later on.

DISTRIBUTION OF BIRDS.

There can be little doubt that it is to the benefit of forestry to encourage the distribution of birds in due proportion as to numbers and as widely as practicable (14). Beal (4) is of opinion that 'as many species should be encouraged as possible with moderation in individuals to induce demand for many kinds of food'. Seasonal changes in distribution are very marked and migration brings in the wide range of summer residents and autumn visitors. Most of the summer residents are insect-eaters, such as the warblers, nightingale, redstart, stonechat, whinchat, the flycatchers, cuckoo, nightjar, swallow, martin, and swift (10, 16). Chaffinches, goldfinches, linnets, yellowhammers, and others are given to flocking and moving about freely as autumn and winter draw on, their numbers being augmented by influxes from the continent; starlings and wood pigeons are notorious for their flocking proclivities.

The type of forest influences the natural distribution of woodland birds (5), and broad-leaved and mixed forests are generally more attractive than pure conifer. This is more true, however, of smaller woods and spinnies of deciduous trees. The Forest of Dean, mainly an oak forest, is singularly birdless except on the fringes of the enclosures. The young conifer forests in East Anglia are displacing the birds of the open heath, such as stone curlew, skylark, and meadow pipit, but are attracting species not previously common to the locality, among which are the willow warbler, whitethroat, wren, robin, whinchat, hedge sparrow, goldcrest, chaffinch, yellowhammer, and blackbird (2). The present stage is one of transition. The permanent redistribution of bird life will not finally be known until such time as a silviculturally correct series of age classes has been established in the forest. This is, of course, true of the afforestation of all lands which have not hitherto borne a forest crop, whether the trees planted be deciduous, conifer, or mixed. It is beyond argument that the broad-leaved belts, which are now being planted, primarily for amenity, by the Forestry Commission in East Anglia and elsewhere will,

as they grow up, attract and hold a number of insectivores and others that do not usually frequent pure conifer forest. Plantations of conifers on upland moors on lands unsuited to hardwoods at once attract additional species; bare moorlands are particularly badly off for small passerine birds other than pipits.

The birds included in the following list will frequent the different types of conifer forest in due season:

Great tit.	Goldcrest.	Crossbill.
Blue tit.	Nuthatch.	Wood-pigeon.
Coal tit.	Siskin.	Green woodpecker.
Crested tit.	Chaffinch.	Great spotted woodpecker.
Long-tailed tit.	Tree-creeper.	The Owls.
Wren	Starling.	The Hawks.
Robin.	Cuckoo.	Capercailzie.
Redstart.	Nightjar.	

Of the foregoing, the coal tit, crossbill, capercailzie, long-eared owl, goldcrest, siskin, and the so far strictly localized crested tit show preference for conifers (10, 16); the others are tolerant if conditions are otherwise to their liking, that is if the woods are not too dry or draughty. The wren will establish itself in conifer woods even at high altitudes. Elton (5) gives a list of no fewer than forty-five species tolerating the conditions in conifer plantations in Britain and says: 'Present afforestation changes (increase of planted conifers) will not much affect the species found, but may bring about lower densities and a re-distribution of species in different stages of vegetation.' One obvious remedy against lower densities is the provision of nesting-places.

Bird populations are regulated by food supplies, nesting requirements, disease, natural enemies, season, and environment. Natural distribution has to some extent been upset in Britain long since, and instances will be encountered where artificial regulation is necessary in the farmers' interests, for example with wild pigeons and starlings at the present time. In general, however, wholesale destruction is always unsound (4); the subject is intricate and demands careful and impartial investigation.

The preservation of game is harmful to bird life only in so far as the needless slaughter of hawks and owls is involved. On some estates a check is kept upon this senseless killing, but elsewhere there is less enlightenment. It is to be feared also that the collector has something to learn, particularly where the rarer species are concerned.

HARMFUL AND HELPFUL BIRDS.

It is indicative of our meagre knowledge that the authorities who have published lists of harmful and helpful forest species have seldom dealt otherwise than superficially with the problem of the wild birds in the woods. The rational course is to encourage as many species as possible (7), and there is not much room for doubt that the titmice, warblers, goldcrest, robin, wren, woodpeckers, cuckoo, nightjar, nuthatch, starling, and all the hawks and owls, including the little owl (1), should be encouraged in the woods, subject, how-

ever, to the remarks previously made concerning the sparrow-hawk. Pheasants, thrushes, and chaffinches are also to be welcomed. The tree creeper's status may be in doubt (15), because it is an eater of predatory as well as helpful insects, and also that of the crossbill, a consumer of pine seed (8, 15). The latter is a bird that will surely increase its numbers considerably in Britain as the newly planted conifer forests reach cone-bearing age. Pending the accumulation of a great deal more knowledge, proscription ought only to be extended to the wood-pigeon and stock dove, as menaces to husbandry at large, and to the roosting starling, both for the damage it does to plantations, and because its numbers throughout the country are now in excess of what they should reasonably be; contradictory as it may seem, the nesting starling is to be encouraged in the woods (15). How far birds such as woodpeckers, tree-creepers, the nuthatch, bullfinch, and others may be responsible for the spread of fungous disease in the forest by the transport of spores on their feet or feathers and by injury to bark and buds are matters of conjecture because nothing is known.

Certain seed and fruit-eating birds are active distributors of tree seeds, particularly the wood-pigeon, rook, jay, magpie, missel-thrush, song-thrush, blackbird, and starling. Holly and hawthorn are extensively spread in this way, likewise the mistletoe in those parts of the country in which it occurs. Seeds of the elder, briar, and bramble are introduced where thrushes, blackbirds, and starlings roost and the larger birds, including the pheasant, are distributors of mast over wide areas.

ENCOURAGEMENT OF BIRD LIFE.

What wild birds need is food and water, a suitable habitat, attractive nesting-places, and protection from foes. It is possible that the provision of drinking-places would help to attract more birds to dry conifer forest; artificial feeding will seldom prove to be practicable, but much might be done by the planting in groups, or along ride-sides, of wild fruit-bearing trees. There is considerable scope for activity at small cost in the provision of suitable breeding conditions and nesting-places. The provision of nesting-boxes for the hole-nesting tits, starling, robin, nuthatch, and redstart should be included in the forest protection section of the Working Plan, particularly in conifer forests where the laying out of wide rides and belts of broad-leaved species, as well as the formation of roadside belts of deciduous trees and bushes, will attract and hold a number of the insectivores and other birds which from time to time include quantities of insect food in their diet, such as the warblers and finches. German experience (7, 14) indicates that at least two nesting-boxes per acre are needed in order to secure successful protection against caterpillar damage. It has been established by the Seebach Bird Protection Experimental Station (14) that the effective range of a pair of insectivorous birds at breeding time extends within a radius of 50 metres from the nest.

The fact must not be lost sight of that the Germans have conclusively demonstrated that the encouragement and protection of birds only promises

success in combating the attacks of insects when used as a preventive and not as a curative measure. Hitherto it has always been shown that success is only to be expected if the birds are brought in before infestation can assume the proportions of a calamity.

OBSERVATION AND RESEARCH.

In Great Britain we have so far relied almost wholly upon private enterprise, and much useful work has been done by the Bird Protection and Naturalists' Societies, and by amateur ornithologists at their own expense. Investigation into economic ornithology has been hindered by the lack of interest and public support and a want of facilities and funds. We fall sadly behind some of the continental governments and that of the United States in this (4), and yet the subject is of great importance to husbandry, of which forestry is one of the branches. The dietary of birds at the different seasons of the year can only be established by the examination of stomach contents, except in the case of the Raptores, Corvidae, &c. which have the habit of throwing up pellets of indigestible material, i.e. bones, hair, feathers, elytra, wings, and scales. Thus very fortunately it is not necessary to shoot numbers of our hawks, owls, and ravens in order to arrive at estimates of their bills of fare. Bird migration is receiving attention, but the whole question of the economic status of British birds is crying out for scientific investigation and assessment. It behoves the forester to look after his avian friends and helpers, and forestry research in Great Britain ought no longer to overlook the problems of economic ornithology.

THE LAW AND THE BIRDS.

The legal position of our wild birds is not at all satisfactory (4). Acts of Parliament bearing upon the subject have been plentiful, and as might be expected the early ones were concerned principally with birds for sport and food although in the Act, 8 Elizabeth, cap. 15, the rook is referred to as a destroyer of grain and the bullfinch as harmful to fruit. The first comprehensive act was the Wild Birds Protection Act of 1880 which, supplemented by subsequent acts (eight in all) prohibiting amongst other things, the use of the pole-trap, and the taking of wild birds by means of hooks, forms the basis of the law relating to wild birds as it stands to-day. No ornithologist views the position with equanimity. The widespread ignorance concerning our native birds was still more widely spread in 1880, consequently the principal motive power behind existing legislation has been an uninformed sentimentality; moreover, the terms of the Act of 1880, and its lack of precision coupled with a general absence of knowledge, have resulted in a certain degree of 'woodenness' in its administration. Attempts have been made to bring the law into line with the information that bird enthusiasts have so far accumulated, but hitherto to no purpose. In the absence of reliable and widely drawn data it was and still is a difficult matter to frame wise laws, but, complicated as the subject remains, there is a very real need for a new act, and it is urgently

necessary that organized investigation into our bird problems be taken in hand systematically. The habits and behaviour of wild birds are closely related to the home production of food and timber.

So anomalous is the present position that even properly accredited investigators cannot obtain all the specimens they require for necessary examination and study without infringement of the law, and a further commentary on the current state of bird protective measures is that the effective preservation of rare species in Britain, such as the kite and honey buzzard, depends upon private enterprise and privately subscribed funds and not on the law of the land. Ornithologists have good reason to be dissatisfied, and there is no logical reason why husbandry (including forestry) should be any more complaisant.

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AN OUTLINE OF RULES AND DIRECTIONS TO BE ADOPTED AGAINST FOREST INSECTS IN SWEDEN

BY IVAR TRÄGÅRDH

(Chief of the Entomological Department, Royal Swedish Institute of Experimental Forestry, Experimentalfältet, Sweden)

DURING the last bark-beetle campaign in Sweden, organized after the exceptional storms of 1931 and 1932, the absence of any laws enforcing the adoption of certain measures prescribed by the forest entomologist was felt to be a severe handicap, sometimes endangering the success of the campaign. The history of the fight against forest insects shows clearly that success often depends on the regulation of the activities of forest owners. Moreover, it is a mistake to look upon insect damage as something exceptional; the control of injurious forest insects should be looked on as one of the daily activities of the forester. The first step towards a solution of this problem must obviously be taken by the forest entomologist. He must be able to offer to the authorities convincing evidence that injuries caused by numerous insects are a common occurrence in the forests, also that heavy economic losses arise as a consequence of this, and, last but not least, that in many instances these losses may be avoided by measures the cost of which represents only a tithe of the losses.

It is obvious that conditions vary so greatly in different countries that it is impossible to draw up a plan of campaign common to all countries. Different measures have to be adopted even in different parts of Sweden owing to the climatic and faunistic differences between its northern and southern regions. Nevertheless, there are numerous features of the relationship between forest management and forest insects which are common to most countries. It is my intention to endeavour to state the principles of such a forest management which would take into consideration the entomological point of view. My attempt may at least serve as a stimulus to other forest entomologists to publish their views on this subject.

A. RULES AND REGULATIONS TO BE FOLLOWED UNDER NORMAL CONDITIONS.

I. *Regeneration of the forest.*

(*a*) *Cones and seed must always be carefully examined and tested before any measures are carried out for the regeneration of the forest.* This is necessary because the cones of pine and spruce, especially the latter, are often attacked by numerous insects, which destroy the seed. The appearance of these insects is periodical, coinciding with the supply of cones and seeds, because the insects may lie dormant several years without developing when the seeds are scarce, reappearing when there is a seed-year. It is impossible to draw any safe conclusions regarding the state of the health of the cones and the seed

from their external appearance. This must be ascertained by special investigations, such as dissecting and shelling of the cones. Generally speaking, it is evident that the results of any measures undertaken for the purpose of regeneration cannot be justly judged unless such a fundamental factor as the supply of seed is known. With such knowledge unnecessary expense for preparing the ground may be avoided.

(*b*) *Barking of stumps when seed-trees are left.* This measure has to be taken because the Greater Pine Beetle, *Blastophagus piniperda*, breeds under the bark of the pine-stumps in the spring following the cutting. The next generation of pine beetles ascends the remaining seed-trees and feeds in the 1 and 2 year old shoots to such an extent that 500 to 600 shoots may be collected under one tree. As a consequence, in northern Sweden and some parts of Smoland the trees often die; if they survive this attack, the loss of needles, buds, and small cones is so great that it will take the crowns three to four years to recuperate before they are able to fulfil their purpose namely, seed-production. This delay involves the loss of three to four years' growth of the new regeneration, and the area becomes invaded by luxurious growth of grasses and herbs which render cultivation difficult and expensive.

(*c*) *Measures against injurious insects in plantations and naturally regenerated areas.* Selection cutting is, whenever possible, to be preferred to clear cutting. The reason for this is that whenever there are many stumps per unit area, the numbers of the Greater Pine Weevil, *Hylobius abietis*, is enormously increased, because this species and its close relation the Smaller Pine Weevil, *Hylobius pinastri*, breed in the stumps and the roots. Both the old and the young beetles feed on the plants in the vicinity of the stumps. Whenever smaller or greater cuttings are made, it is always safe to assume that the pine weevil will be abundant in the spring two years afterwards. The damage may be considerably reduced if measures are taken in order to ensure that the young plants at that time are either so small (1 year) that they escape injury or so vigorous (4 to 5 years) that they may survive the attack without serious damage.

The biology of *Hylastes ater* and *H. cunicularius* is sufficiently similar to the Pine Weevil that injury by them is avoided by the same measures.

If natural regeneration has been obtained in smaller clearings or these clearings have been cultivated, these areas must not be enlarged until after four to five years. The reason for this is that according to all experience these freshly cut stumps attract the pine weevils in great numbers and they feed on the young plants before mating. It must be emphasized that this injury cannot be prevented by barking the stumps, because even the barked stumps would attract the beetles, which would feed on the plants.

It is imperative that cultures and regenerations should be as dense as conditions allow, and that the development of openings is prevented. The propagation of some primary insects such as the Pine-shoot Moth is so greatly favoured by open stands that severe infestations may take place if this is not done. These destroy the stem form, and hence no timber but only fuel is obtained.

II. *Treatment of young stands.*

(a) *Early cleaning.* If thinning is carried out so early in young pine stands that it may be called cleaning and the diameter at the base of the cut trees does not exceed 3·5 cm., no special measures are necessary against bark-beetles. The Greater Pine Beetle, *Blastophagus piniperda*, the only species from which danger threatens, cannot propagate in such slender stems, because although the beetles make egg-galleries of almost normal size, the number of beetles produced is smaller than the parent generation.

(*b*) *Later cleanings.* If the cut stems have no value and thus it is most economical to leave them in the stand, it is imperative not to do the thinning during the winter or spring before the swarming of the pine beetles. Unless this measure is adopted, the Greater Pine Beetle, *Blastophagus piniperda*, will breed in the same spring in such felled stems as have thick bark. The next generation feeds during the last half of the summer in the crowns of the remaining trees, especially in the tops, which may be deprived of almost their entire assimilating surface. As a consequence, in southern and middle Sweden there is a decrease in increment, which may amount to 30 per cent. as well as deterioration of the stem form. In northern Sweden this loss may cause the death of the trees. Such cleaning must not start in southern or middle Sweden until the beginning of June, that is after the swarming of the beetle, which has only one generation a year. Trees cut after this time and until early autumn may be left on the ground, because next spring they will not be attacked by the pine beetle but by secondary insects of no importance.

(*c*) *Thinning in young spruce forest.* No measures are necessary against forest insects in this case because young spruces have too thin bark for the Spruce Bark Beetle, *Ips typographus*; moreover, the Six-toothed Bark Beetle, *Pityogenes chalcographus*, which breeds under thin bark, prefers to breed in the tops and twigs, and does not as a rule attack the standing trees.

III. *Thinning in other Stands.*

From an entomological and silvicultural point of view, it is imperative that the stands are thinned at the proper time so as to ensure that suppressed and backward trees are removed. Pines with undersized crowns always offer sooner or later breeding material for pine beetles and *Pissodes pini*, and may become centres of more severe attacks. The common occurrence of the Greater Pine Weevil in a stand is almost always a sure sign that thinning has been neglected. The same applies to spruce stands, because suppressed spruce of the fourth crown layer succumbs to the attack of *Pityogenes micrographus* or *Cryphalus abietis* or *C. saltuarius*.

On very dry, sandy soil with low ground-water level great care and watchfulness are necessary after exceptionally dry summers. These circumstances favour the propagation of *Pissodes piniphilus*, which breeds in the crowns to such an extent that next year the pines succumb to the combined attack of *Blastophagus piniperda* and *Blastophagus minor* and form centres for an outbreak of these insects. It is true that the attack of *Pissodes piniphilus* cannot

be prevented. On the other hand, this attack being discovered by examining the conspicuous flow of white resin in the top of the stems, the pine trees attacked next year by the pine beetles may be detected so early that the trees may be barked and the attack stopped.

IV. *Logging.*

(*a*) *Logs must not under any circumstances be left unbarked in the forest during the summer.* Pine logs must be barked before the middle of May in southern and middle Sweden and before the middle of May in northern Sweden. Spruce logs must be barked before the middle of May in southern and middle Sweden and before the middle of June in northern Sweden. There are two reasons for this measure. Firstly, the logs deteriorate owing to the attack of blue-stain fungi, which always accompany the invasion of bark beetles. Secondly, the logs offer excellent breeding material to the bark beetles and may become centres of infestations. Even if only 50 per cent. of the bark surface is utilized by the Spruce Bark Beetle, the production may rise to 4,700 beetles per log. This means that four unbarked logs may produce as many bark beetles as is normally found per hectare in a normal spruce forest. The corresponding figure for the Greater Pine Beetle, *Blastophagus piniperda*, is 3,200. If, after exceptional happenings such as storms, it is not possible to log the timber at the proper time, the logs must be stacked in as great piles as possible, and the piles stacked on as dark and damp localities as possible and covered all round by a thick layer of moss.

(*b*) *Pulpwood must be barked before the middle of May.* Unbarked pulpwood offers breeding material for several species of bark beetles.

(*c*) *Fuelwood must be cut in the spring and stacked fully exposed to the sun.* This is the only method to avoid making the fuel wood stacks breeding-centres for bark beetles. It is not possible, however, to prevent the breeding of bark beetles, but the mortality of the larvae owing to the drying of the wood is so great that the production of beetles becomes low. As a good illustration of the enormous number of bark beetles which may issue under favourable conditions, I may mention that a stack of 22 pieces of 20 cm. d.b.h. may produce 50,000 bark beetles. If pine tops are split for fuel, the bark side must be turned up, because this is a sure method of preventing the breeding of the Smaller Pine Beetle, *Blastophagus minor.*

(*d*) *Treatment of slash.* Larger defective butts and other waste material must be barked before the end of June. Owing to their generally thick bark they dry very slowly, and thus are excellent breeding material for bark beetles. Since they have no value, the deterioration of the wood due to blue stain, &c., may be neglected, hence they may be used as trap-trees and barked only in time to destroy the brood.

B. GENERAL HYGIENIC MEASURES IN THE FOREST.

The insects are a perfectly normal part of the biocaenosis of the forest, and, owing to their high biotic potential, the balance is very easily upset if

conditions alter in their favour in only one respect, and an outbreak may start. For this reason, it cannot be strongly enough emphasized that the forester must always be on the look-out and carefully consider the entomological consequences which his actions may give rise to.

Instances of serious damage caused either by neglected thinning or by thinning at a wrong time of the year in pine forests have already been quoted. Even in the most carefully managed forests, however, local outbreaks may occur which, if not detected early enough to enable the forester to destroy the brood, may develop into more serious outbreaks. For this reason, the forester must make himself familiar with the symptoms which accompany the initial stage of the attack; only by so doing will he be able to stop the attack at its beginning. The old routine of deferring the cutting and barking of dying trees until the winter must be abandoned, because by this time all the bark beetles have generally left the trees.

Pine beetles: Blastophagus piniperda and *B. minor.* It is fairly easy to recognize the attack of these beetles, because they occur so early in the season that the growth of the young shoots is either stopped or distinctly lowered. On such trees, one always finds brownish-white dust in the crevices of the bark as a corroborative evidence of the attack of the beetles. These trees should not be cut or barked immediately, but be used to their utmost capacity as trap-trees until all the eggs are deposited. Then, but not before, they must be barked and the brood destroyed.

Pissodes pini is more difficult to detect. As already pointed out, its common occurrence in a stand is generally a sure sign that thinning has been neglected. The beetle very often starts its attack in places where the bark has been wounded by the felling of other trees. On the other hand, this species does not complete its metamorphosis until the next year. Hence felling and barking in the autumn is sufficient. The presence of *Pissodes piniphilus* may be detected by means of great, white, mirror-like patches of resin in the top of the tree caused by the feeding and oviposition of the beetle.

Spruce Bark Beetle: Ips typographus. This beetle normally appears about a month later than the pine beetle. The length of the shoots is not influenced to such an extent that this symptom may be used as indication of the attack. Later, the needles discolour very slightly, but unfortunately this discoloration may be imperceptible or entirely absent. If the attack starts low down on the stem, the boring dust is easily detected. If higher up, one must use field glasses in order to detect the entrance holes. In order to confirm this it is useful to beat the trunk with the back of an axe to see if needles and dust fall.

Finally, it must be emphasized that it is very important to be on the look-out when catastrophes which favour the propagation of bark beetles occur, such as storm, fire, snow-break, inundations, and exceptionally dry seasons.

THE DEPLETION OF STARCH FROM TIMBER IN RELATION TO ATTACK BY *LYCTUS* BEETLES

I. STARCH, WITH SPECIAL REFERENCE TO ITS OCCURRENCE IN TIMBER

BY E. W. J. PHILLIPS

(Forest Products Research Laboratory, Department of Scientific and Industrial Research)

INTRODUCTION.

IN recent years considerable attention has been paid to starch in timber, both in connexion with the relation of starch to the other contents of the wood cell and the components of the cell wall (7, 8, 55, 56), and in connexion with the attack of timber by wood-destroying organisms. It is with the latter aspect that the present paper is primarily concerned; it aims at describing the nature of starch, the manner in which it occurs in timber, and the principles to be employed in removing it, together with an outline of the physiological problems involved. This paper is intended to serve as an introduction to others in this series in which an account will be given of work carried out at this Laboratory, principally by Dr. E. A. Parkin of the Entomology Section, on various practical methods of depleting timber of its starch and thereby rendering it immune to attack by *Lyctus* Powder-post beetles (29, 36, 53).

THE NATURE OF STARCH.

It is unnecessary here to discuss in detail the formation of starch. Its elaboration from carbon dioxide of the air and water in plant leaves is a complex sequence of processes which have defied reproduction *in vitro*, although Baly's recent work (3) suggests that this is not beyond the limits of possibility. The minute starch grains formed in the leaf by specialized portions of the living protoplasm are converted, presumably by a catalytic amylase system, into soluble sugars which are transported to other parts of the plant where reconversion to starch, probably by a similar enzyme system, takes place. Of present interest is the fact that in trees a considerable amount accumulates as a reserve in the sapwood of the main stem where, as in roots, tubers, and other plant organs commonly utilized for storing such reserve foodstuff, relatively large grains of starch are re-formed from the transported sugars.

A variety of shapes is shown by these grains in different plants: spheroidal, ellipsoidal, polygonal, discoid, rod-like, and even dumb-bell-shaped grains have been observed (31), but within each species a characteristic and limited range of form occurs. Usually some grains are present in the form of aggregates either as compound grains, aggregates of two or more (30,000 in the case of *Spinacia glabra*) (50), individual grains, or as half-compound grains composed

of a number of individual grains which fused at an early stage in their development, the aggregate subsequently becoming totally enveloped by further layers of starch. Individual grains vary from 1 micron to over 100 microns (0·1 mm.) in diameter; in the few timbers so far examined they have been fairly small, rarely exceeding 10 microns in average diameter (cf. 7). Under the microscope many varieties of starch show concentric or eccentric stratification around a nuclear point or hilum. This stratification is not readily discernible in the small grains found in many timber species, but the appearance of dark interference crosses when the grains are viewed between crossed nicols indicates that a regular, organized structure is present. In some starches internal cavities, fissures, and even external pores are to be seen. For observations of such details staining is desirable: safranine, gentian violet, and gentian violet followed by picric acid have been recommended (26). A dilute solution of iodine in aqueous potassium iodide solution is also useful for this purpose particularly for grains within plant cells. A concentration of 0·1 per cent. iodine has been found suitable; with stronger solutions a darker coloration is obtained tending to obscure details. For observations of the path followed by enzyme solutions in penetrating starch grains, Grüss (16) has found guaiacum to be a suitable reagent.

Finality has not been reached regarding the composition and constitution of starch, but a vast amount of work has been carried out relating to this subject and a fairly clear conception is now possible. Much of this work is covered in a recent review by Hanes (18) on the constitution of starch in relation to enzyme action. That starch is composed largely of a polysaccharide of the empirical formula $(C_6H_{10}O_5)_n$ has long been established, and it is now known to consist of chain molecules each containing some thirty α-glucose residues arranged probably in the form of a spiral, each coil of which contains six residues. These large molecules associate to form colloidal particles, and it has been suggested that the small amount of phosphorus present in starch forms nuclei around which the starch molecules aggregate. Amylopectin, the more viscous fraction, and amylose, the more hydrophilic and fluid fraction into which starch may be separated, have been shown to be identical in chemical composition. Their differing physical properties are attributed to differing modes of aggregation of their molecules. Intergradation between the two substances occurs and each may be fairly readily converted into the other. The proportion of each fraction normally present varies with the variety of starch. It may be noted that relatively little work has yet been carried out on wood starch in particular; its isolation for chemical study was first accomplished by Campbell as recently as 1933 (46), and the extent to which it agrees in composition and properties with other kinds of starch has not yet been fully ascertained.

The structure of the starch grain has been the subject of several hypotheses, and these have recently been reviewed by Badenhuizen (2). The latest observations tend to support the micellar conception of Nägeli put forward in 1858. Under certain conditions each layer of the grain may be seen to consist of

radially arranged cubic particles each approximately 1 micron across; it has been suggested that these particles represent bundles of radially arranged amylose micelles and that the substance separating the particles is amylopectin.

Starch grains are insoluble in cold water, alcohol, and other common organic solvents, but dissolve in cuprammonia, alkalis, and solutions of certain inorganic salts. Intact grains are much less readily affected by reagents than mutilated grains in which the inner substance is exposed. With warm water swelling occurs, succeeded by dispersion of the grains to form an opalescent solution, which, on cooling, forms a paste. This property of paste formation has been known and made use of in the stiffening of fabrics for nearly three thousand years (21). The temperature of pasting varies with the kind of starch and the duration of heating; rye starch pastes at as low a temperature as 50° C., but acorn starch may require 87° C. (24). Timber which has been steamed shows a similar dispersion of its starch grains. The extent of variation in properties and reactions of different starches is well demonstrated by Reichert's observations on 350 kinds (45). Differences between these kinds are sufficiently marked to enable the starch of one variety of plant to be distinguished even from that of another variety of the same species, and McNair (27) has more recently arranged these data in a form suitable for purposes of systematic identification.

Under the action of certain enzymes and acids, starch is converted to dextrins, maltose, and finally glucose. Such conversions are a normal feature of the metabolism of the plant cell, and although they can be brought about *in vitro*, the artificial product, even when extracted plant enzyme is used, differs from that formed in the living cell, indicating that extracted enzymes markedly differ from the intact enzyme system of the plant cell (18). Microscopic observations during starch dissolution in plant cells, for example in germinating barley, generally reveal corrosion of the starch grains, which begins at certain points, and proceeds internally until only the outer coats of the original grains remain; these are perforated by small pores through which the degraded contents are removed (5). Preliminary observations on wood starch during depletion processes have not revealed such stages of dissolution, but indicate that the grains are attacked selectively one by one and entirely dissolved; the remaining grains appear intact and unaffected.

Sufficient has been said to indicate that starch may be met with in timber in a variety of forms and conditions. It is evident that starch is to be regarded as a complex of substances, or rather, of different physical forms of a single substance, and that the starches of different botanical species may have distinctive physical features and somewhat different properties. In dealing with depletion in the various timber species, therefore, differences in behaviour may be anticipated, owing to specific differences both in the properties of the starches and in the enzyme systems; a depletion process successfully applied to the starch of one timber may not be equally successful when applied to another.

THE RECOGNITION AND ESTIMATION OF STARCH.

Starch may generally be recognized in timber either by the form, structure, and physical properties of the grains as observed in microscopic sections of the wood, or by examination of the surface of the timber itself after treatment with iodine-potassium iodide solution. Under the microscope the granular form, together with the interference crosses to be seen under crossed nicols, may be regarded as diagnostic for starch. For detecting minute quantities certain reagents have been developed, e.g. iodine-chloral hydrate and iodine in Eau-de-Javelle, which combine the functions of dissolving obscuring substances in the plant cells, dispersing the starch, and simultaneously staining it (31, p. 387).

For determining the starch content of wood quantitatively at least four chemical methods are applicable. (i) Hydrolytic methods, involving hydrolysis of the starch by enzyme or mineral acids, after removal of other reducing substances, and estimation of the sugars produced (17, p. 102). (ii) Fractional extraction, depending on the fact that cell contents other than starch can be extracted with water first, at relatively low temperatures, without affecting the starch which is subsequently extracted at a higher temperature (7). Spoehr and Milner (49) have used a similar method of extraction; they employ a freezing treatment to precipitate the starch from solution. Another method of this type involves successive extractions with alcohol-benzene, acid-alcohol, and finally alcohol (32). These techniques are intended primarily for isolation of starch rather than its accurate estimation. (iii) Extraction with a saturated solution of calcium chloride followed by precipitation of starch with iodine and gravimetric determination of the starch iodide; the iodine present is then determined by the thiosulphate method and the quantity of starch found by difference. (Fellenberg's method as described by Gäumann (14).) Sullivan (51) has made use of the starch extraction process of this method, but follows this by hydrolysis of the starch iodide and estimation of the glucose formed. (iv) Colorimetric methods, apparently first described by Dennstedt and Voigtländer (see 17), involve dispersion of the starch, addition of iodine, and comparison of the depth of the blue colour produced with those produced by standard starch solutions. A critical investigation of such methods has been made by Paloheimo (34).

It may be noted that results obtained by the first method are liable to error owing to hydrolysis of cell-wall polysaccharides related to starch (7, 14). The remaining methods all involve some form of extraction, and unless this is checked by microscopic observation of samples tested with iodine the results may be unreliable; the effectiveness of extraction is also apt to vary with the size of the particles to which the tissue is ground (7).

A physical method of determining the starch content of living wood has been described by Wilson (54). Paired samples are taken and the specific gravity of one determined, while the other is sealed to prevent drying and allowed to respire. When this process is complete (as shown by the gas analysis method) (53), the specific gravity of this second sample also is determined. The difference between the two specific gravity values measures the loss in dry weight

which has occurred in the second sample owing to the depletion of its reserve material during the course of respiration. Unfortunately, removal of the starch may be incomplete so that the values obtained are apt to be too low; the time involved is another serious drawback of this method.

One disadvantage of all these methods, however, is that they yield but little information on the distribution of starch in the various tissues. For this and other reasons it has sometimes been found more convenient to fall back on a visual method of estimating the amount of starch present, using an arbitrary series of grades. Hartig and Weber (1888) (19) appear to have been the first to use such a method. In work at this Laboratory a system of this kind comprising seven grades has been evolved; the following procedure in estimating the starch content has been adopted throughout this work. The specimen to be examined, usually a board or auger boring, is planed or pared with a razor or knife, to expose a clean, obliquely radial surface—a rough surface gives misleading results; iodine-potassium iodide solution is then applied. A much stronger solution of this reagent is required than that recommended for microscopic observations (p. 16). A concentration sufficient to give rapid and deep staining of the starch without unduly darkening the wood is desirable so that good contrast between the stained starch and the wood is obtained. A solution containing about 0·5 per cent. of iodine has been found most satisfactory.[1] In research on the various home-grown timbers the entire width of the sapwood zone is usually examined, and for comparative work the starch concentration for each annual ring, or alternatively for each tenth of an inch or other arbitrary unit, is recorded; for such observations a low-power binocular microscope giving a magnification of about ×30 has been found most convenient. Precise verbal definition of the starch grades employed is difficult, but the notes in the following table together with Fig. 1, Plate I will give an idea of the appearance of the starch concentrations implied. In certain cases differences in the concentration of starch in the various tissues are apparent, and it is then necessary to make an appropriate mental adjustment for this in arriving at the average grade.

TABLE I. *System of visual grades of starch concentration* (see Fig. 1, Plate I).

Grade number.	*Starch concentration.*
0	*Nil.*
1	*Trace.* Isolated cells containing odd grains present.
2	*Very small amount.* Several starchy cells present averaging very few grains apiece.
3	*Small amount.* Starchy cells only moderately numerous and mostly very incompletely filled.
4	*Fair amount.* Starchy cells numerous but mostly incompletely filled.
5	*Moderate amount.* Starchy cells numerous but several incompletely filled.
6	*Abundant.* Cells packed with grains very numerous.

[1] To prepare this reagent, the potassium iodide crystals (1 gm.) should be dissolved in a small quantity of water (5 c.c.) and the iodine crystals (0·5 gm.) then added. When these have dissolved add water to make up to 100 c.c. Cf. (11).

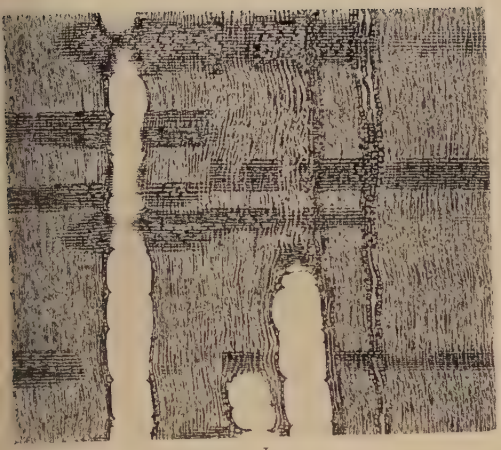
This scheme was evolved in the first place for dealing with English ash (*Fraxinus excelsior*), and in applying it to other timbers the relative proportions of potential starch-containing tissues have been taken into account so that the records for various species are roughly comparable, and consequently have the advantage of being approximate measures of susceptibility to *Lyctus* attack; for example, a starch concentration of grade 4 in ash may be presumed to render the wood as equally liable to attack as a grade 4 concentration in any other susceptible species of timber.[1] With a little practice, rapid and consistent estimation of these starch grades is possible, and while for the purposes for which this system has so far been used knowledge of the actual starch contents or of the quantitative differences between successive grades has not been required, it is believed that the visual grades could readily be correlated with parallel quantitative determinations. Starch concentrations corresponding to grade 3 or less appear, from observations carried out by Dr. E. A. Parkin, to be insufficient for normal development of *Lyctus* larvae in timber.

THE DISTRIBUTION OF STARCH IN TIMBER.

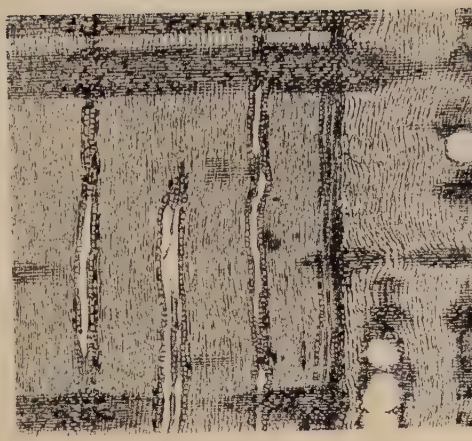
It is to be noted, at this point, that all trees do not lay down their chief food reserve in the form of starch; in many species, for example, many conifers, lime, and certain species of birch and poplar (48), and also sweet chestnut (6, p. 358), it takes the form of fatty substances. Various attempts have been made to correlate the type of food reserve with the character of the wood and with anatomical features. 'Starch trees' frequently produce dense wood while that of 'fat trees' is usually softer (12, 15); ring-porous woods commonly have starchy, and diffuse-porous woods fatty reserves; and broad-rayed species tend to store starch (48); but there are many exceptions and there appear to be no rules capable of general application. It is not known whether fat can be utilized as food by *Lyctus* larvae, but it is unlikely that it can form a substitute for starch to any extent. However, fat trees commonly contain a certain amount of starch, and for this reason their timber cannot be regarded as immune from *Lyctus* attack.

In the woody portion of the tree, starch (and fat if present) is normally confined to the living cells of the parenchymatous tissues of the sapwood and only rarely occurs elsewhere, for example, in the fibres of sycamore, *Acer pseudoplatanus*. The normal starch-containing tissues of the wood are (i) the rays, which communicate *via* the cambium with phloem tissues just inside the bark, and (ii) the vertical strands of wood parenchyma which in many woods are closely associated with the sap-conducting vessels. The cells of the rays and of the wood parenchyma communicate with one another at certain points and comprise, in effect, a single tissue system. The distribution of the two

[1] The susceptibility of a timber to *Lyctus* attack is determined not only by its food content but also by the diameter of its vessels. Of home-grown species only a few, including ash, elm, chestnut, oak, sycamore, walnut, and willow, have pores large enough to receive the beetle's eggs (35).



1



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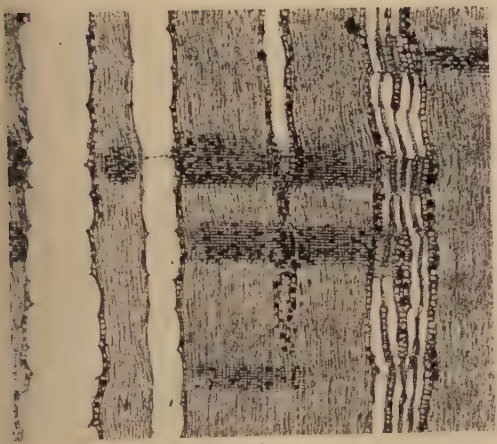

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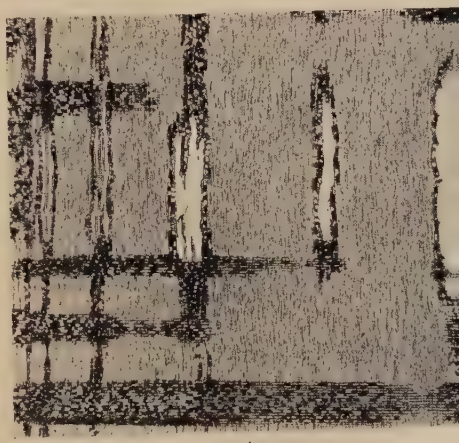

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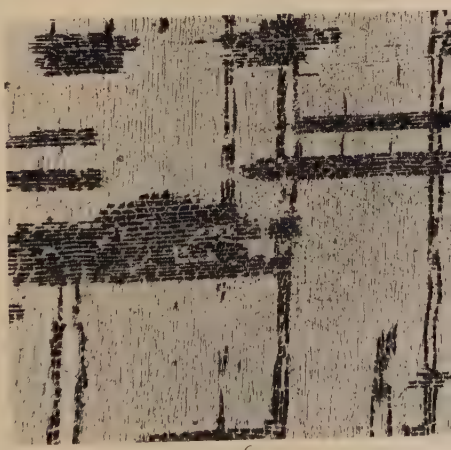


6

FIG. 1. Visual grades of starch content in ash (*Fraxinus excelsior*). (×20)

PLATE I

tissues on end-grain surfaces of certain hardwoods susceptible to *Lyctus* attack is shown diagrammatically in Text-fig. 1. Both rays and wood parenchyma are composed of brick-shaped cells, the small end-walls of which are usually well pitted, apparently facilitating translocation in the direction of the long axis of the cell, horizontally in the case of the rays, vertically in the wood parenchyma.

Rays are present in all timbers but constitute a varying proportion of the wood in different species. Meyer (30) showed that the average ray volumes of American woods ranged in conifers from 3·4 to 11·7 per cent., averaging about 8 per cent., and in hardwoods from 5·3 to 42·3 per cent. averaging 17 per cent. Few published figures are available for the proportionate volume of wood parenchyma, but it is known to vary considerably; certain softwoods have none, while in such timbers as iroko (*Chlorophora excelsa*) (see Text-fig. 1) and silky oak (*Cardwellia sublimis*) it is a prominent feature. In hardwoods the rays and parenchyma together commonly form as much as 25 per cent. of the total volume.

The proportions of starch-storing tissues within a species appear to be dependent on conditions affecting the vigour of the tree. Hartig (6, p. 115) observed a marked increase in ray volume in oak after thinning; it has also been shown (13, 23) that reduction in the parenchymatous tissues occurs when lowland species are grown under alpine conditions. External conditions affecting growth vigour also markedly influence the total amount of functioning parenchymatous tissue owing to their effect on the width of the sapwood zone; a wide sapwood normally accompanies free development of the crown (38, 39, 40, 47).

The actual quantity of starch stored appears to vary considerably according to the species of wood, as is shown by the following figures.

TABLE II. *Starch content of sapwood in common timber species (per cent. of dry weight of wood).*

Species.	*Starch content %.*	*Investigator.*
Alder	1·54	(4)
Ash	2·4	(55)
Beech	0·2	(14)
Birch	0·95	(4)
Elm	5·9	(4)
Horse chestnut	6·7	(55)
Maple	2·65	(4)
Oak	1·38	(7)
	2·1	(55)
Sweet chestnut	2·65	(4)
Sycamore	3·5 and 4·7	(55)
Walnut	0·43	(7)

In those starch trees which show a distinct heartwood the sapwood normally contains some starch throughout; as the innermost sapwood becomes converted

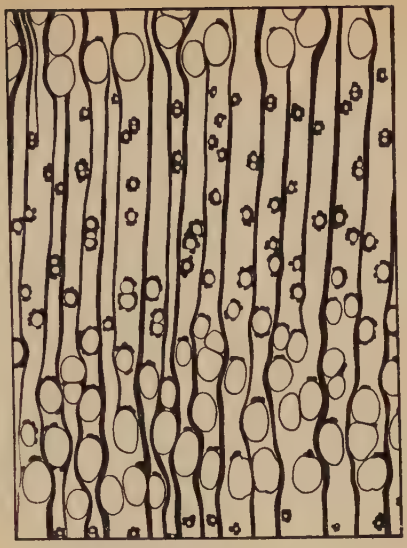
to heartwood, however, its starch normally disappears, in some species leaving no trace, in others becoming transformed into coloured substance of uncertain composition (28, 56); rarely some unaltered grains persist, e.g., in walnut (*Juglans regia*). Trees normally forming no distinct heartwood ('sapwood trees'), e.g., ash (*Fraxinus excelsior*) and beech (*Fagus silvatica*), have a wide starchy zone, but sizeable trees have a starch-free core. On the whole, starch content within the sapwood zone diminishes towards the centre of the tree, but the decrease is often irregular, certain zones retaining a greater amount than concentric zones on either side. The variation throughout the length of the trunk at any given time is also irregular; in some cases it tends to increase towards the crown and in others it may decrease (52, and observations by the writer on ash).

Several investigators have recorded seasonal variation in the quantity of wood-starch. For deciduous trees in temperate climates it has been well established that there is a maximum in the trunk at leaf fall and a secondary maximum in early spring; while corresponding minima occur in the periods of dormancy and growth respectively. The spring depletion corresponds with fresh growth of leaf and shoot; the autumn maximum is the cumulative result of photosynthetic activity throughout the preceding summer. The other fluctuations, however, appear to be less related to the growth rhythm of the tree. Since the winter minimum is followed by a maximum in early spring before photosynthesis begins, it is evident that the starch is merely transformed temporarily into a different kind of reserve substance. It has been suggested that the transformation represents a means of protecting the living cells against the action of frost (6, p. 356; 42) by increasing the concentration of dissolved substances in the cell sap and thereby lowering its freezing-point. This phenomenon is of some importance in the *Lyctus* problem since winter-felled wood may give a misleading impression of low food reserves. In evergreen species also two maxima and minima are said to occur, but in this case the spring maximum is higher than that of the autumn; this is attributed to the initial activity of the old leaves in spring (22). According to Coster (10) the well-marked periodicity in starch content variation shown by European species is lacking in the tropics, but, nevertheless, slight decreases accompany the formation of new leaves or new wood; no loss of starch through transformation into other reserve carbohydrates takes place.

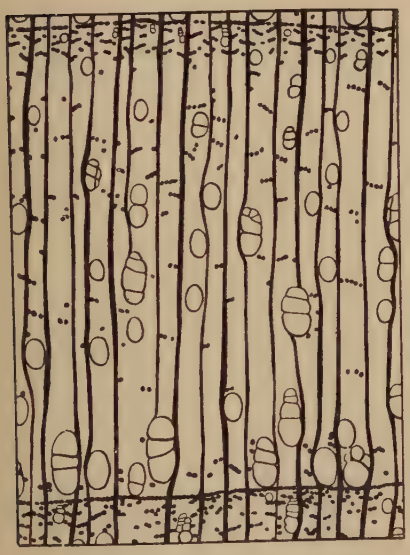
THE FUNCTIONS OF STARCH IN THE TREE.

The outstanding characteristic of reserve starch in plants is the readiness with which it may be transformed to sugars and reformed from these substances; the 'starch-sugar ratio' may be rapidly adjusted to meet varying requirements through the mechanism of the plant's enzyme system. The effectiveness of these changes is attributed largely to the fact that sugars are soluble and osmotically active whereas starch is insoluble and inert. Thus variation of the 'starch-sugar ratio' brings about changes in the water-absorbing capacity of the cell and constitutes a mechanism for controlling water

a



b



c

d

TEXT-FIG. 1. *Distribution of Storage Tissues.* (Transverse sections × 15. Storage tissues in solid black; pores in outline.)

(*a*) Oak (*Quercus robur*) showing rays of two sizes, very broad and narrow; parenchyma forming ill-defined bands between strands of summer-wood pores.

(*b*) Ash (*Fraxinus excelsior*) showing narrow rays; parenchyma mostly associated with summer-wood pores.

(*c*) Walnut (*Juglans regia*) showing narrow rays; parenchyma mostly in short tangential lines and also forming a line at the boundary of the annual ring.

(*d*) Iroko (*Chlorophora excelsa*) showing rays of medium width; parenchyma surrounding the pores and extending to form irregular tangential bands; occasional narrower bands independent of the pores.

movement throughout the parenchymatous tissues. It is often important in connexion with depletion work to distinguish between temporary transformation of this kind and actual removal of starch. *Lyctus* larvae can make use of sugars (36), although it is not known to what extent these can adequately replace starch in the insect's diet.

The most apparent function of the large food reserve stored during the resting period is provision for spring growth, and it has been shown (6, p. 352) that in some timbers, e.g. oak, the reserve is more than adequate for this purpose, sufficient being present to form a second crop of leaves should the tree suffer defoliation but insufficient to repair two successive defoliations. In other species, e.g. sycamore, spring growth results in complete loss of starch (9). Apart from such differences between species it is a general rule that older trees and older parts of trees are less completely cleared of starch than young ones. Some of the deeper-seated reserve in old trees, however, may be stored in dead cells of no use to the tree. The fate of the starch in spring is not yet known, though it has been widely presumed to be concerned with leaf formation, and with the initiation of cambial activity, and several investigators have shown that starch is lost first from the buds and then progressively down the tree. There is abundant evidence, however, that the new wood is built from the carbohydrates synthesized during the current year (6, p. 164; 25).

The greatest demand on the starch reserve of the stem has been shown by R. Hartig (6, p. 354) to be for seed production, and he considered that the frequency with which seed years recur is dependent on the period required by the tree to build up the necessary reserve. Tubeuf (6, p. 355) observed that in willow, ash, and maples only one to two years is required; in sweet chestnut and elm, two to three years; in oak, three to five years, and in beech a partial seed crop occurs every three to four years and a full one every ten to fifteen years. Hartig observed that beech, which otherwise contains much starch in autumn, possesses only a trace after the production of a full seed crop. This marked difference in starch content of fruiting and non-fruiting beeches is confirmed by Gäumann's recent determinations (14).

The necessary energy for synthetic processes in the living cells of the wood is derived from the combustion of reserve materials. The commonest form of this process is aerobic respiration during which starch is converted to carbon dioxide and water; this is brought about at ordinary temperatures and normally without any marked liberation of heat through the agency of a complex system of enzymes. Respiration continues throughout the life of the cells and is not entirely in abeyance even in the so-called dormant periods; it proceeds most actively during the growing season.

Priestley and Tong (43) observed in a number of species that greater lignification on the lower side of branches was accompanied by a higher starch content there than on the upper side, and Record (44) noted that in conifers generally thickening of the tracheid walls is more pronounced where these are in contact with ray cells, apparently a result of locally superior nutrition.

These observations are of particular interest in view of Campbell's finding that starch is closely related chemically to certain important constituents of the wood cell wall (7, 8). Evidence is also available (56) that starch is utilized in the formation of gummy materials by the tree as a reaction to wounding, and it is worthy of note that reserve materials may constitute an important factor for success in forest pruning practice. Starch appears to play a similar part in forming substances of some protective value at heartwood formation (41).

Of these various functions in which starch is concerned only respiration results in loss of food material from the tree as a whole, although some of the processes may involve its translocation from the trunk to other parts of the tree or its utilization for structures of a permanent nature such as cell walls.

In this brief review of the functions of starch in the living tree no account has been taken of the metabolism of other food substances, for example nitrogenous materials, but it is recognized that these may influence or limit the part played by the starch reserves.

STARCH DEPLETION.

In considering the production of starch-free timber two factors must be taken into account: (*a*) fluctuations of the starch content of the living tree, in order to ensure a minimum at the start, and (*b*) the continuance of vital activities in the timber so as to remove the remainder of the stored food. In research on practical methods of depletion it has been found desirable, in order to test the efficacy of a process fully, to use timber having a relatively high starch content; in commercial practice, however, factor (*a*) would be taken into account where possible.

Respiration is the process of paramount importance in all methods of depletion, and this is only possible so long as the storage cells of the wood remain alive. The enzymes concerned in respiration will continue to catalyse isolated reactions after the death of the cells, but for the co-ordination of the various reactions involved and for the maintenance of a continuous supply of enzymes, normal functioning of the living protoplasm is essential. In felled timber death of the living cells owing to drying out is one of the chief dangers to be guarded against. Interference with normal respiration may result in the conversion of starch to coloured substances resembling those commonly found in heartwood (54, 56).

It is known that respiratory activity may be accelerated by various means. The fact that the rate of respiration increases with temperature (up to a limit of about 40° C.) has been shown by Henderson's experiments (20) to be applicable in accelerating the removal of starch from wood. Marked increase in the respiration rate may also be brought about by fluctuations in temperature (33). The use of chemical stimulants, already applied commercially to the storage and maturation of fruit and other vegetable produce (cf. 1), is another possible means which has not yet been investigated of speeding up depletion in timber. For a discussion of the fundamental botanical researches

on this and other aspects of respiration reference may be made to Palladin's text-book (33).

The various methods of depleting timber of its starch content so far investigated have already been outlined by Parkin (37). In the following paragraphs these methods will be discussed in the light of the preceding considerations.

(i) *Girdling methods.*

The practice of removing rings of tissue from plant stems has been one of the most generally used experimental methods of botanists in their work on the translocation of substances within the plant. The effect of girdling depends largely on the depth to which the girdle is cut, and to a certain extent on the season at which the operation is carried out. When a band of tissue is removed to the depth of the cambium the downward passage of substances manufactured in the crown is interrupted at the girdle, although, as noted by Loomis (25) after a short period (4–6 weeks) partial downward translocation of organic material may be resumed apparently as a result of an increase in permeability of the cells adjacent to the girdle, with the result that substances pass into the wood and thus move past the interruption in the outer tissues. Deeper incision will tend to prevent this partial resumption of downward passage, but will also interfere with the ascent of the sap stream.

The effect of girdling during the period of active growth would appear to have a more drastic effect on the tree than if the operation is made prior to the commencement of growth, since in the latter case some adjustment to the altered conditions is possible. In some cases it should be possible to take advantage of the fact that a considerable quantity of starch is removed from the trunk for fruit and seed production (see p. 24).

(ii) *Storing of logs in the round with bark intact.*

In this method the ends of the logs may be coated with an antiseptic moisture-proofing substance to hinder drying out. The essential problem here is the maintenance of a suitable balance between allowing the necessary gas exchange and simultaneously preventing loss of moisture (which would result in drying and consequent death of the starch-bearing cells). This would appear to call for consideration of the permeability of the bark tissues which will vary from species to species and with the age of the bark. Means of maintaining suitable temperature conditions having regard to the effect of temperature on respiration and on the movement of gases and moisture have also to be considered. Attack of the logs by injurious organisms is one of the chief practical difficulties connected with this process.

(iii) *Storing of logs in water.*

This method overcomes certain of the disadvantages of method (ii), particularly in minimizing the danger of attack by wood-destroying or staining organisms, in preventing moisture loss, and in allowing greater control of the temperature factor. The affinity of carbon dioxide for water may result in

some acceleration of the respiratory process, although the low concentration of oxygen in stagnant water may call for artificial aeration in order to maintain normal aerobic respiration. Leaching of soluble reserve substances is another possible factor tending to hasten depletion by this method.

(iv) *Kiln-treatment of converted stock.*

This is attractive in cases where rapid depletion is of paramount importance. The process, however, calls for more highly technical control than those already mentioned since it is necessary to employ a relatively high temperature (around 40° C.) in order to accelerate respiration, and also to maintain a high humidity and so minimize moisture loss. Death of the respiring cells and fixation of the starch soon results if the temperature is allowed to rise much above the optimum temperature for respiration, and excessive moisture loss through inadequate humidity control has a similar effect. On the other hand, if the drying rate is kept down by maintaining a high relative humidity, these conditions will favour the growth of mould and sap-staining fungi.

Experimental work on girdling standing trees, special methods of storing logs, and kiln treatment of converted timber will be described in other papers in this series.

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SUMMARY.

This paper forms an introduction to a series dealing with practical methods of depleting timber of its starch content with a view to rendering it immune to attack by *Lyctus* Powder-post beetles. The available information on starch is summarized and considered with special reference to this problem. Variations in the structure, composition, and physical properties of starch are noted. Several chemical methods of starch determination are mentioned and a visual method for estimating the amount and distribution of starch in timber is described. The storage system of trees and the physiology of reserve food materials (especially starch) are described and discussed. Finally the principles of starch depletion and the difficulties involved in various practical methods are considered.

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THE DEPLETION OF STARCH FROM TIMBER IN RELATION TO ATTACK BY *LYCTUS* BEETLES

II. A PRELIMINARY EXPERIMENT UPON THE EFFECT OF GIRDLING STANDING OAK TREES

BY E. A. PARKIN

(Forest Products Research Laboratory, Department of Scientific and Industrial Research)

INTRODUCTION.

IT has long been known that many phytophagous insects can digest the starch which so commonly occurs in plant tissues, but it was not until 1893 that the dependence of certain wood-boring insects (*Anobium*, *Lyctus*) upon starch in timber, as their main source of nourishment, was suggested by Mer (10, 11). Although no evidence has yet been forthcoming to support Mer's contention that larvae of *Anobium* require starch for successful development, there is abundant evidence of the necessity of an adequate supply of this carbohydrate for larvae of the *Lyctus* Powder-post beetles.

By chemical analysis of sound oak sapwood and frass, Campbell (3) has shown that *Lyctus* larvae are unable to digest the cell-wall constituents and must, therefore, rely upon the cell contents for their nutriment. Wilson (15), Cummins and Wilson (5), and Parkin (12) have established by investigation of a number of species of susceptible woods that starch is the principal food material of *Lyctus* larvae. The last author has also shown that a water-soluble substance is necessary in oak sapwood for normal larval development, and, by feeding larvae in glass tubes upon an artificial diet containing only starch, sucrose, and protein, has confirmed that cell-wall constituents are quite unnecessary. In reviewing their own work and that of other investigators, Beeson and Bhatia (2) conclude that members of the family Bostrychidae, which is very closely allied to the Lyctidae, similarly feed upon the cell-reserve materials and not upon the cell wall.

In view of the great economic importance of the *Lyctus* Powder-post beetles to the hardwood timber trade, which has been discussed by Fisher, Cann, and Parkin (6), and because development of the larvae is impossible in the absence of starch, the commercial production of starch-free timber would be a big step forward in the control of the Powder-post beetles. Starch occurs in the majority of timbers only in the sapwood, and its depletion therefrom would permit the safe utilization of much sapwood which at present must be discarded. There are four processes by which considerable reduction or complete depletion of the starch in green timber may be achieved: (i) girdling the standing tree, (ii) storing logs in the round with the bark intact, (iii) storing logs under water, (iv) special kiln treatment of converted stock. Research upon these methods has been in progress at the Forest Products Research

Laboratory during the past five years as part of a general investigation upon the *Lyctus* Powder-post beetles. The present paper, forming part of a series dealing with the occurrence of starch in the sapwood of certain hardwoods and with methods of bringing about its resorption, embodies the results of a preliminary experiment to ascertain the effect of girdling upon the starch content of four standing oak trees. It is intended to deal in later papers with the other methods of producing starch-free timber.

STARCH DEPLETION BY GIRDLING.

The girdling of standing trees was investigated by Hartig (7) in 1859. He found that trees girdled in early spring add an incomplete annual ring and that there is an accumulation of starch above and depletion of starch below the girdle. In 1893 and 1903 Mer (10, 11) published accounts of his work on the prevention of insect attack in timber by girdling and log storage, and considered the possibility of preparing starch-free wood commercially. He points out that the phloem must be completely severed during girdling, and that resorption of starch is more rapid if both top and base of the trunk are ringed: oaks double girdled in May were starch-free by November. Trees should not be left standing beyond the first winter or fungi invade the exposed tissues. Du Sablon (14), Baldwin (1), Loomis (9), Cline and MacAloney (4), and Leach (8) have all made observations on girdling which confirm the results of Hartig and Mer. Girdling in spring may therefore be expected to result in an accumulation of reserve carbohydrates above and a partial or complete resorption of these substances below the top girdle. It appears from the experiments of the above workers that, if the bark, phloem, and cambium are cut through, the flow of water up the sapwood is not interrupted, but food materials manufactured in the leaves are unable to descend through the phloem past the level of the girdle. Below the girdle, therefore, the sapwood cells are cut off from their food supply, but, in the presence of an adequate moisture supply, continue to live upon their own reserves until these are completely resorbed, when the tree dies.

MATERIAL AND METHODS.

Since Mer (10, 11) carried out his work on oak, a timber in which *Lyctus* infestation is very abundant, it was decided to use this species in the present investigation. Through the co-operation of Messrs. John Stenning & Son, Ltd., Timber Merchants and Sawmillers, of East Grinstead and Robertsbridge, Sussex, four standing oak trees (*Quercus robur* L.) at Fern Wood, Vinehall Estate, Robertsbridge, were placed at the disposal of the Laboratory for experimental purposes. The trees were in a wood growing on a well-drained undulating side with coppice and bracken undergrowth; Nos. 175, 185, A. 135, and A. 147 were selected for girdling.

All four trees were girdled at the top of the trunk and two (185 and A. 135) received an additional girdle 4 ft. above the ground (Fig. 1). The girdle was made by chopping or sawing through the bark round the tree at two levels

4 to 6 inches apart, then prising off the ring of bark with a barking tool. In order to ensure that the continuity of the phloem and cambium had been broken, a notch about 1 inch wide and $\frac{1}{4}$–$\frac{1}{2}$ inch deep was chopped round the sapwood in the middle of the girdle. All leafy twigs and small branches below the girdle were then cut off. Trees 185 and A. 135 had a top girdle on the main stem just below the first fork. Trees 175 and A. 147, on the other hand, forked rather low down and a ring of bark was consequently removed from each of the main branches a little distance above the fork.

Table 1 gives general data on the trees.

TABLE I. *General data on experimental trees*

	Tree number.			
	175.	*A. 135.*	*A. 147.*	*185.*
Girth (breast height)	55 in.	81 in.	83 in.	44 in.
Age	100 yrs.	114 yrs.	100 yrs.	72 yrs.
Approximate width of sapwood	1·20 in.	1·20 in.	1·30 in.	1·60 in.
No. of rings per inch of sapwood	22	14	15	13
Height of girdles:				
Top	33 ft. 0 in.	16 ft. 0 in.	25 ft. 0 in.	21 ft. 0 in.
Bottom	..	4 ft. 0 in.	..	4 ft. 0 in.
Date of girdling	10.7.35	10.7.35	10.7.35	10.7.35
Date of felling	16.12.35	16.12.35	14.12.36	14.12.36

The starch content of the sapwood of each tree was determined at the beginning of the experiment from an increment boring taken at breast height; additional borings were taken from just above the top girdles of trees 185 and A. 147. Short lengths of branchwood from trees 175 and A. 147 were brought back to the Laboratory for infestation by *Lyctus*; a 1-inch board was sawn from the middle of the piece and this was dried rapidly over a radiator in order to fix the starch.

TABLE II. *Original starch content of borings and branchwood*

	Tree number.			
	175.	*A. 135.*	*A. 147.*	*185.*
Boring (4 ft. 6 in. from ground)	Rings 1–5 none	1–5 small	1–17 moderate to abundant	1–3 none
	Rings 6–26 fair to moderate	6–17 moderate to abundant	18–19 none	4–21 moderate to abundant
Boring (above top girdle)	..	..	1–3 none	1–4 none
			4–19 moderate to abundant	5–19 moderate
Branch	Abundant in rays; small to moderate in xylem parenchyma	..	Abundant in rays; small to moderate in xylem parenchyma	..

The amount of starch present in the trees at the start of the experiment is indicated in Table II. The grades of starch used throughout this paper

PLATE II

FIG. 1. Tree A. 135 showing upper and lower girdles

FIG. 2. Sapwood from tree A. 135 after exposure to *Lyctus* infestation. Upper sample from branch above

correspond to those described by my colleague E. W. J. Phillips (13) in the first contribution of this series.

The spring crop of leaves was fully developed when the trees were girdled on 10 July 1935. This probably accounts for the lack of starch in the outer rings of the sapwood. The girdling was carried out rather late in the year, since Hartig (7) found that it should be undertaken before the end of June, and Mer (11) recommends May.

RESULTS OF GIRDLING.

(1) *Effect on Starch Content.*

(*a*) *Trees 175, A. 135.* These two trees were felled on 16 December 1935, that is, about five months after girdling. Disks, 12–15 inches long, were sawn from each tree at the base, middle, and top of the trunk, the bottom and top disks including the girdles. Pieces of large (8 inches diameter) and small (3 inches diameter) branchwood were also collected. In addition, a series of increment borings was taken at intervals along the length of the tree from the butt to above the top girdle. The quantity of starch present in all samples and borings was subsequently estimated (Table III).

TABLE III. *Starch content of borings from trees 175 and A. 135 felled five months after girdling*

Tree 175.		*Tree A. 135.*	
Height from ground.	*Starch content.*	*Height from ground.*	*Starch content.*
1 ft. 6 in.	Nil	1 ft. 6 in.	Rings 1–11 nil 12–14 trace 15–16 moderate
9 ft. 6 in.	,,	Girdle (4 ft. 6 in.)	
14 ft. 6 in.	,,	4 ft. 6 in.	Nil
19 ft. 6 in.	,,	7 ft. 6 in.	,,
24 ft. 6 in.	,,	10 ft. 6 in.	,,
29 ft. 6 in.	,,	13 ft. 6 in.	,,
32 ft. 0 in.	,,	Girdle (16 ft.)	
Girdle (33 ft.)		16 ft. 6 in.	Rings 1–16 rays moderate; parenchyma very small
34 ft. 6 in.	Rings 1–5 abundant 6–10 moderate 11–15 very small 16–21 nil	19 ft. 6 in.	Rings 1–9 abundant 10–17 moderate
40 ft. 0 in.	Rings 1–10 abundant 11–15 moderate 16–21 very small	25 ft. 0 in.	Abundant

The sapwood from the base up to the girdle of tree 175 was entirely devoid of starch, which was first detected about 12 inches above the girdle; a little higher up the sapwood contained moderate to abundant starch throughout.

This tree, as will be observed from Table II, contained a little less starch at the start of the experiment than the others.

Tree A. 135 was girdled at top and bottom, but some traces of starch were found in the trunk below the lower girdle in those portions of the rays near the heartwood; the outer portion of the sapwood was entirely free from starch. Between the girdles no starch could be detected. A trace of starch was visible in rays near the heartwood about 2 inches above the upper girdle, and the amount increased rapidly until at 6 inches above the girdle moderate starch was present throughout the rays, and a little could be seen in the xylem parenchyma. A few feet higher the sapwood contained abundant starch throughout.

Specimens from each of the disks were exposed to attack by *Lyctus brunneus* during July 1936, and examined in September 1937 (Fig. 2). Samples cut from the branches above the top girdle of both trees were very severely infested, and numerous exit-holes were present. Portions of the disks cut at the levels of top and bottom girdles and at an intermediate height showed no signs of exit-holes. On planing the surface of these pieces it was evident that eggs had been laid in all the specimens and that the young larvae hatching therefrom had died after tunnelling a millimetre or two. One exception must be noted, however, for a single living larva, 1·5 mm. long and therefore scarcely larger than first stage, was found just under the surface where a trace of starch was present. So few grains were visible, however, that the larva could not have completed its development.

(*b*) *Trees A. 147, 185.* This pair of trees was allowed to stand over a second summer, during which both produced a sub-normal quantity of foliage. They were felled on 14 December 1936, disks were selected as before, and borings taken at intervals along the length of the trunk.

TABLE IV. *Starch content of borings from trees A. 147 and 185 felled seventeen months after girdling*

Tree A. 147.		*Tree 185.*	
Height from ground.	*Starch content.*	*Height from ground.*	*Starch content.*
4 ft. 0 in.	Rings 1–17 trace	Girdle (4 ft. 6 in.)	
15 ft. 6 in.	Rings 1–13 nil	5 ft. 0 in.	Nil
	14–17 trace	10 ft. 0 in.	,,
24 ft. 0 in.	Nil	14 ft. 0 in.	,,
Girdle (25 ft.)		20 ft. 0 in.	,,
29 ft. 0 in.	Rings 1–5 moderate	Girdle (21 ft.)	
	6–20 abundant	22 ft. 0 in.	Rings 1–11 nil
33 ft. 0 in.	Rings 1–5 moderate		12–20 very small
	6–20 abundant	25 ft. 0 in.	Rings 1–17 abundant
39 ft. 0 in.	Abundant		18–22 moderate
		27 ft. 6 in.	Abundant
		30 ft. 0 in.	,,
		34 ft. 0 in.	,,
		39 ft. 0 in.	,,

The sapwood immediately below the girdle of tree A. 147 was devoid of starch; half-way down the trunk a trace of starch was detected in the rings next to the heartwood, and near the base of the tree scattered grains could be seen in the whole width of the sapwood. Above the girdle starch was present in abundance. Tree 185 was found to be free from starch below the top girdle, except for a few scattered grains in some of the rays where they entered the heartwood; this trace of starch was seen only in the disk cut at 12 feet 6 inches above ground-level. Starch was detected about 9 inches above the top girdle and rapidly increased in quantity until it was abundant in the sapwood 4 feet above the girdle. Results are not yet available of experiments on the infestation by *Lyctus* of portions of the disks.

(2) *Effect on Susceptibility of Tree before Felling to Fungus and Insect Attack.*

The sapwood of all samples and borings taken at the start of the work was white and free from any signs of fungal discoloration or decay.

(*a*) *Trees 175, A. 135.* Five months after girdling, examination, in co-operation with the Mycology Section, of disks and borings from trees 175 and A. 135 showed that fungus had gained an entry to the sapwood through the girdles but had not spread far. In tree 175 a staining fungus had caused the outer 0·3–0·5 inch of the sapwood to assume a greyish-brown colour for about 1 foot above and below the girdle respectively. The remainder of the wood was free from infection. Tree A. 135 was a little more seriously affected, as might be expected, since it had two girdles. In the region of the lower girdle the outer 0·3 inch of sapwood was stained greyish-brown, but a little decay was also present, probably caused by *Stereum hirsutum* or *Polystictus versicolor*. The middle disk showed only very slight traces of stain which was of no importance. At the level of the upper girdle the outer 0·5 inch of sapwood was stained and some decay was also present: 3 feet higher the wood was free from any signs of decay or discoloration.

(*b*) *Trees A. 147, 185.* Staining and decay were more marked in trees A. 147 and 185, which had been left standing for 17 months after girdling. In tree A. 147 a disk, about 12 inches long and including the girdle, showed the sapwood in this region to be badly decayed by a wood-destroying fungus, subsequently identified in culture as *Polystictus versicolor*: the outer 0·5 inch also showed a greyish-brown discoloration due to a staining fungus. Four feet above the girdle no fungus was seen and 10 feet below the wood appeared free. It is not known how far the stain or decay had spread down the trunk. The sapwood of tree 185 was severely decayed in the region of the top girdle, and a little decay was mixed with stain in the outer 0·4 inch at the lower girdle. A disk taken from between the two girdles was apparently unaffected, but microscopic examination revealed the presence in the rays of a few hyphae, probably of a staining fungus.

The only evidence of insect attack on the trees was a short abandoned tunnel on the top girdle of tree A. 147: it had a diameter similar to the borings of *Ptilinus pectinicornis* or *Platypus cylindrus*.

CONCLUSIONS.

The foliage of the trees, which were in leaf at the time of girdling, was apparently unaffected by the treatment during the first summer, but was reduced in quantity during the next season. This might be explained by the fact that in the spring of the second season the trees could not call upon a full reserve of starch for the purpose of leaf production, since it was found that, five months after treatment, starch was absent from or present only in traces in the sapwood below the top girdle. On the other hand, above the top girdle starch was present in abundance, but a tree cannot, presumably, lay down sufficient reserve materials in the crown alone since storage space is obviously limited. It was thought that the girdling had been carried out rather late in the year and that it would have been better to ring the trees before the leaves appeared, but the results indicate that the starch had been depleted quite adequately by the time the first two trees were felled, and there appeared to be no further depletion in the trees left standing for another year. There was no evidence to show that a bottom girdle had accelerated the rate of starch depletion, indeed, this second girdle was a disadvantage, since it provided an additional area of unprotected tissue through which staining and wood-destroying fungi entered the sapwood. Very little degrade was caused by fungi in the two trees felled during the first winter after girdling, but the infection had, naturally, become more severe in the trees which were not felled until the second winter. There is a possibility, however, that painting the girdles with creosote soon after they have been cut might prevent even the small amount of degrade through staining which was apparent in the trees felled during the first winter.

This preliminary experiment shows quite clearly that girdling standing oaks is a promising method of rendering the sapwood free from starch and, therefore, immune from *Lyctus* Powder-post beetle attack. The number of trees used in the experiment was too small, however, to indicate whether there is likely to be much variation in the rate of disappearance of starch between different trees, and it is proposed to investigate this point, a larger number of trees being top-girdled and felled during the first winter after treatment.

ACKNOWLEDGEMENTS.

I wish to record my thanks to A. Colin C. Darby, Esq., and Harold E. Stenning, Esq., of Messrs. John Stenning & Son, Ltd., for their interest in the investigation, for placing the trees at the disposal of the Laboratory, and for having the girdling carried out as directed.

SUMMARY.

Four oaks (*Quercus robur* L.) were girdled at the top of the main trunk through bark, phloem, and cambium in July 1935: two of the trees were also girdled near the base. One pair was felled after 5 months, the other after 17 months. In all four trees the sapwood below the upper girdle was rendered devoid of starch and the presence of a lower girdle did not seem to accelerate

the depletion. Stain and decay fungi entered the sapwood at the girdles, the deterioration being negligible after 5 months but rather marked after 17 months. The starch-free sapwood was shown to be unsuitable for the development of larvae of *Lyctus* Powder-post beetles.

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THE SHRINKAGE AND EXPANSION OF WOOD

BY W. C. STEVENS

(Forest Products Research Laboratory, Department of Scientific and Industrial Research)

INTRODUCTION.

IT is a well-known fact that when sufficient moisture has been removed from green wood, further drying tends to cause the overall dimensions of the piece under consideration to decrease, whereas a subsequent rewetting will cause an increase in these dimensions. It has further been generally accepted that shrinkage does not occur until a definite stage in the drying has been reached, and that the subsequent shrinkage from this stage is proportional to the moisture-content loss (1). It has also been assumed that providing the movements are unrestrained, the dimensions of the wood are fixed and definite at any given moisture content, irrespective of whether previous drying or rewetting has taken place.

Such assumptions do not appear to have been entirely borne out by exact tests made over a very wide range of moisture contents, but to a certain extent to have been arrived at from considerations of the manner in which the timber is supposed to yield up its moisture.

It has been generally agreed that the free moisture held in the cell cavities of the wood is first removed on drying, and that eventually a stage is reached when the cell cavities are empty but the cell walls still saturated. This free moisture was regarded as being incapable of exerting any appreciable shrinkage pressure under normal atmospheric conditions, so that its removal would result in no decrease in the overall dimensions of the wood. Subsequent removal of moisture from the cell walls, however, invariably appeared to be accompanied by shrinkage which was found to be proportional to the weight of moisture removed. If then, proportionality persisted while any of this hygroscopic moisture was being removed or replaced, it would obviously be sufficient to know the shrinkage at any two moisture contents below the saturation value in order to estimate the dimensions at any other moisture-content value. Tests have generally shown such an estimate to be reasonably correct at comparatively low moisture contents, but at the higher moisture-content values discrepancies have been noted. In particular, it had been observed that in estimating the minimum moisture-content value to which a piece must be rewetted just to reach its green dimensions, two distinctly different values could be found by considering first the shrinkage in the direction of the annual rings and secondly the shrinkage normal to the annual rings. This particular moisture-content value, which ought to correspond with that at which the cell walls are saturated and the cell cavities empty, should, according to the above assumptions, have one definite value for each species. This value is usually referred to as the fibre-saturation value (2). Estimates made of this

fibre-saturation value for various species have generally shown it to lie between 25 and 30 per cent. moisture content.

Shrinkage tests made on comparatively large wood sections have often shown a dimensional decrease at moisture contents well above this estimated fibre-saturation value, but it had been usual to assume here that the surfaces of the wood had dried in excess of the bulk of the material, and that slight shrinkage had been able to occur when the average moisture content of the piece was still comparatively high. The difficulties involved in maintaining wood at comparatively high, uniform, and constant moisture-content values, have indeed usually invalidated any shrinkage values obtained at moisture contents much above 20 per cent. The main sources of error arise from the fact that to maintain wood at moisture-content values higher than the above figure, the air needs to be very nearly saturated, and quite apart from the inherent difficulties of saturating air to this degree, very accurate control of the temperature is essential if precipitation of moisture is to be avoided.

Recent work by Barkas (3) in this Laboratory has, however, suggested that the shrinkages observed at high moisture contents are real and not due to the above-mentioned causes. His work has further indicated that there is no well-defined fibre-saturation value, and that there may be a large moisture-content hysteresis at the saturation value itself.

With a view to obtaining further data on these points, tests have recently been carried out at the Laboratory to determine what may be termed the 'normal' and unrestrained shrinkage of wood from the green to the dry state at normal atmospheric temperatures.

MATERIAL AND APPARATUS.

At the outset it was apparent that if shrinkage free from restraint of any kind were to be obtained, the samples used must be small and be dried in such a manner that the contained moisture remained throughout the process as uniformly distributed as possible. Since the measurements were to be made with a micrometer capable of measuring accurately to 0·001 inch, the samples had necessarily to be reasonably rigid though small, and the dimensions finally decided upon were 3 inches by $\frac{1}{4}$ inch, as measured across the grain, and $\frac{1}{8}$ inch in the longitudinal direction. The wood used was home-grown beech, and twelve specimens were cut and prepared from a segment of a log of green material in the manner illustrated in Fig. 1.

Six specimens (*T* in Fig. 1) were cut so that the annual rings were almost parallel to the length of the specimens and six so that the rings were roughly at right-angles to the length (*R* in Fig. 1).

All the specimens in one set were contiguous along the length of the log and measured no more than $\frac{1}{8}$ inch each in this direction. As soon as the specimens were cut and prepared, they were measured by means of the micrometer in the direction of their largest dimension, i.e. in the direction approximately parallel with the annual rings in the case of those specimens marked *T* in Fig. 1, and in the direction approximately at right-angles to the

rings in the case of those specimens marked *R*. It was then assumed that, since most of the drying would take place from the comparatively large areas of the end-grain surfaces, and since these were no more than $\frac{1}{8}$ inch apart, moisture gradient effects would be very small, especially if the drying rate were slow.

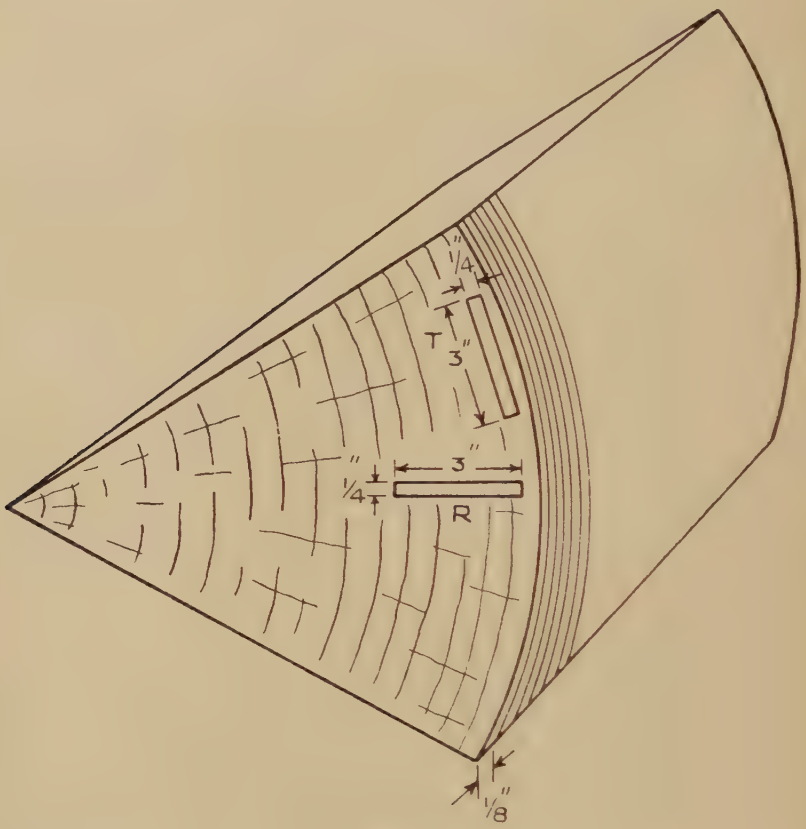

FIG. 1.

PROCEDURE.

The method evolved for drying these specimens slowly at the higher moisture contents was to place them in a large sealed desiccator which was subjected to the small atmospheric temperature changes which normally occur in a room of a building. These changes were found to be sufficient to condense small quantities of the moisture in the air inside the desiccator, and by removing the condensate at long intervals, it was possible to dry samples at the rate of about 9 per cent. moisture content a week. After a moisture-content of about 20 per cent. had been reached in this manner, sulphuric acid solution was admitted to the desiccator, and the concentration increased at intervals. By this method, the moisture-content was lowered slowly by steps to about 2 per cent., when phosphorus pentoxide was introduced and the desiccator evacuated so as to extract the moisture which

remained. After drying, the samples were rewetted over H_2SO_4 solutions so that the cycle was completed. Wetting at moisture contents over about 20 per cent. was effected by spraying the samples evenly at intervals with an atomizer.

RESULTS.

From the numerous weighings and measurements taken, the shrinkage-moisture content relationships both in the direction of the rings (tangential) and normal to the rings (radial) were obtained and are illustrated graphically in Fig. 2.

It may be seen from these curves that shrinkage was recorded at a moisture content as high as 50 per cent. and that at 40 per cent. moisture content the shrinkage of all samples was appreciable. An approximately linear relationship between shrinkage and moisture content is seen to exist below, but not above, a moisture content of 20 per cent., and this linear relationship persists to zero moisture content. Further, the swelling and shrinkage are virtually coincident up to a moisture content of 20 per cent., but the limit of the linear relation does not appear to be reached on rewetting until a moisture content of about 30 per cent. is reached. The result of this is that a very definite hysteresis loop is formed at the higher moisture-content values.

DISCUSSION.

Assuming that these curves can be taken as accurately representing the swelling and shrinkage of small wood sections free from mechanical restraint, it would appear that either the fibre-saturation point is much higher than is generally supposed and the shrinkage-moisture content relationship is not linear from this point, or shrinkage can and does occur while the moisture in the cell cavities is being removed.

It is realized that, in spite of the precautions taken, slight moisture gradients must have existed even in these small specimens, and that such gradients in conjunction with internal stresses set up thereby might have affected the results. Such criticisms cannot be effectively refuted when other than microscopic sections are used, and the drying rate is made infinitely slow, but it is reasonable to suppose that the recorded tangential shrinkage of no less than 2 per cent. at a moisture content of 35 per cent. cannot be entirely accounted for by such small moisture gradients as might have existed. In this connexion also it must be remembered that only the gradients along the length of the sample, as distinct from the gradients between the two drying end-grain surfaces, could effect the measurements made, and these are likely to be small owing to the slower drying in this direction.

It is generally agreed that in certain circumstances, more particularly with rapid drying at high temperatures, the capillary moisture exerts considerable surface tension stresses on the walls of the cells, which stresses may actually cause the cells to collapse and in this manner diminish the area of cross-section (4). It is not therefore unreasonable to suppose that the more normal

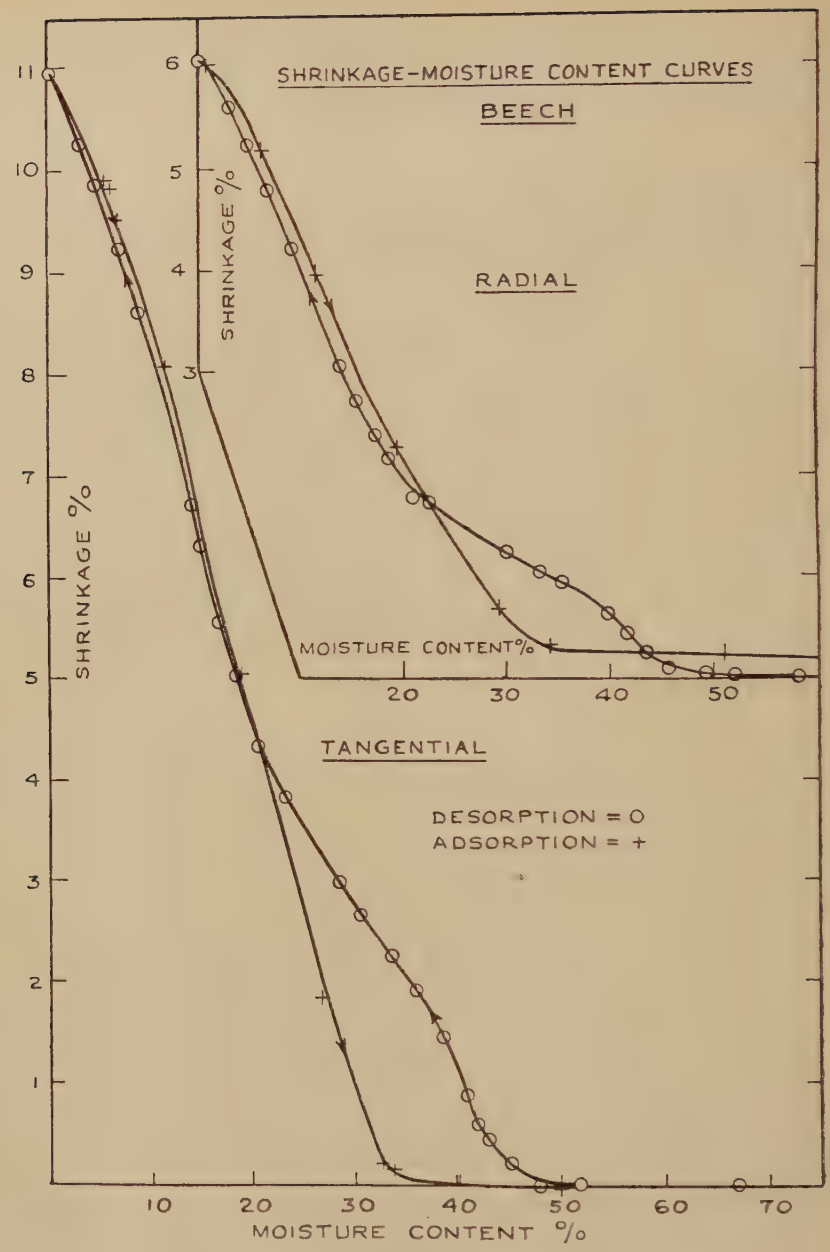
SHRINKAGE-MOISTURE CONTENT CURVES
BEECH
RADIAL
TANGENTIAL
DESORPTION = O
ADSORPTION = +
SHRINKAGE %
MOISTURE CONTENT %
SHRINKAGE %
MOISTURE CONTENT %

FIG. 2.

shrinkages observed at high moisture contents and at atmospheric temperatures are a direct result of similar stresses, and are associated with the drop in vapour pressure found on the desorption curve in the experiments recently carried out by Barkas as previously mentioned.

SUMMARY OF RESULTS.

The results of the above-described series of tests indicate:

(1) That shrinkage starts at a comparatively high moisture content, probably as a result of the forces induced by the extraction of moisture from the cell cavities;

(2) That the shrinkage-moisture content relationship is not linear until a moisture content of about 20 per cent. has been reached, and even then it is only approximately so, and

(3) That a definite hysteresis loop occurs for drying and wetting above a moisture content of about 20 per cent.

ACKNOWLEDGEMENTS.

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SOCIETY'S AND OTHER NEWS

NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

MEMBERS are reminded that nominations for election of office-bearers and councillors at the Annual General Meeting in 1939 must be in the Secretary's hands by 31 October next. There is no special form of nomination, the only requirement being that the nomination must be in writing and be signed by TWO Professional Members (i.e. Fellows or Associates). As the only function of the nomination is to have the nominee's name placed on the list of candidates, there is no advantage in having the nomination signed by more than two Professional Members nor in having more than one nomination (for the same office) in favour of any candidate.

Nominations are required for the following:

Office-bearers, to hold office for one year: President,[1] Vice-President,[1] Editor of Journal,[1] Business Editor,[1] Secretary and Treasurer, and Auditor.

Councillors, to hold office for two years: THREE (Professional Members). A list of those now in office will be found at the beginning of this number. The retiring office-bearers and Councillors are all eligible for re-election.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THIS year's meeting of the British Association will be held at Cambridge from the 17th to 24th August. The Chairman of Section K* (Forestry) is Sir Roy L. Robinson, Chairman of the Forestry Commission, and the Secretary is Mr. Thomas Thomson, Forestry Department, University College of North Wales, Bangor. On Thursday, 18 August, the Chairman will open the proceedings of the Section with an address on 'The Home-grown Timber Supply'. This will be followed by a series of papers forming a Symposium on 'The Cultivation of British Hardwoods'. The symposium will extend over the sessions of the Thursday and Friday and will conclude with a general discussion. Saturday will be devoted to an excursion to a number of forest estates and nurseries, and on Sunday, 21 August, the members will visit the Thetford Forest belonging to the Forestry Commission. On Monday morning, 22 August, there will be a joint discussion with Section K (Botany) on the 'Ecological Aspects of Afforestation'. In the afternoon of that day 'Some Soil features of the Wareham heaths' will be described and discussed by Professor Neilson-Jones and others.

It has been the aim of the officers in framing the programme to arrange sessions devoted to a few main themes rather than a number of unconnected papers on various subjects. The two main subjects: The Cultivation of Hardwoods and the Ecological Aspects of Afforestation are of wide interest and should provide material for useful discussion. It is hoped that there will be a large attendance of persons interested in forestry. Particulars of membership of the Association and detailed programmes may be obtained from 'The Secretary, British Association, Burlington House, London W. 1.

[1] Each must be a Fellow resident in Great Britain.

REVIEWS

Practical British Forestry. By C. P. Ackers, M.A., B.Sc. Oxford University Press, 1938. Pp. 369, 2 appendices, index, and a Foreword by The Rt. Hon. Lord Clinton, P.C. Price 15*s*.

Review by W. L. Taylor

MR. ACKERS, whose interest in British forestry is well known, has written a book for those dealing with the practical side of estate forestry and for the student. It is a readable book and contains much that is wise and helpful to those responsible for the management of woodlands. That it is based on the queer jumble of ancient woodcraft, empiricism, individual observation, and science that has gone to the making of British forestry is beside the point, because the last word upon the practice of forestry in this country will not be written for many a long day.

In his introductory chapter the author discusses the various natural and man-made conditions foresters have to face up to in Britain. Choice of species, espacement, pruning, and thinning are shown to be factors in the production of timber of quality, and clearly he is a protagonist of the mixed plantation and, in general, of close planting, but larch at 8 ft.×8 ft. bodes ill for the quality of the resulting crop and not too well for the condition of the forest floor and conservation of the soil. The importance of proximity to markets is, of course, relative. It is vital in the case of small stands, but in any area large enough to be dignified by the term forest, the annual *coupe* will certainly find its market; quantity and not locality will prove to be the criterion. In policy it is urged that the forester's aim should be the best financial yield over the rotation rather than the maximum yield from the final crop, and it matters much that a woodland owner shall be able to 'rest content in the knowledge that that bit of God's earth which he has been cultivating is handed over to his country at his death more full of beauty for immediate enjoyment, and more full of stored wealth to be used in time of need, than it was when he took it over', a philosophy that none will controvert and one to be commended to those in charge of the very many acres of neglected and understocked woods in this country to-day.

A description of the principal native and acclimatized British forest trees, their silviculture and utilization, occupies 102 pages. In these days of plywood the old stigma 'weed' may not be altogether applicable to the birch as a British forest tree. Well-grown, home produced birch of the right type and size will surely find a market ready to receive it, and there is much low quality, frosty land, such as the poorer Bunter sands, on which the species is easy to establish and will grow to perfection. The discussion on the introduced conifers from the Pacific Coast of North America will be read with interest and particularly so in regard to the Californian Redwood, a tree that has not yet been given its place in British forestry. The value of the numerous references to South African conditions throughout the book is not, however, so obvious.

Rabbits are heartily condemned, and although they 'have been responsible for the general bad conditions of woodlands' the real responsibility lies on broader backs than those of the rabbits and has hitherto so laid far too easily. There are some useful hints in the chapter on 'nursery work' which, as the author states, does not aim at being exhaustive. It is interesting to note that the old text-book fetish of green-manuring is only referred to tentatively and is not upheld as a specific.

The section on 'planting and establishing' is dealt with on informative rather than the conventional lines of so many previous writers. It is in thinning and pruning that so much British woodland has suffered neglect. Mr. Ackers has given careful study to the theory of thinning and pruning and gives valuable information as to methods and tools. Pruning, to be of value, must be done in the early stages of growth, and despite disparagement of the saw for hand pruning, great caution should be exercised in permitting any but experienced men to adventure into the woods with edged tools. *En passant*, however, it may be said that it is perfectly easy to brash larches by means of a heavy stick, or mace, without bruising, if the proper period is chosen.

'Extraction, conversion and sale' are dear to the author's heart, and what he has to say on these subjects includes much sound common sense, but the reasons our home growers are in such an unhappy position in competition with foreign supplies are simple enough. They are twofold: (1) intermittent supplies, (2) inadequate organization and co-operation. Felling costs vary from district to district; haulage is never at its cheapest unless carefully organized, and organization is difficult where relatively small parcels of timber are concerned. The section on conversion is of all the more interest as it is the result of practical saw-milling experience, but the plant described is really something more than an estate saw-mill. The disposal of timber is an important section that would have borne some elaboration, particularly as to bases of valuation. It is almost always greatly to the advantage of the private grower to sell his standing trees subject to measurement after felling. In discussing the future it is right to say that the systematic cropping of woodlands for a sustained yield is in its infancy in Britain. It is also an unfortunate fact that there is no effective check to hinder the cutting of immature plantations, and the result of this freedom on our home timber resources is undoubtedly serious. It is urged that control ought not to be irksome to any right-minded woodland owner and that some check is necessary in the national interest. Bad forest management should be penalized equally with bad farming, and it is no more right and proper to allow the devastation of woodland to go unrepaired and to allow woods to remain neglected and understocked than it is for the farmer to grow thistles and permit the rabbit to increase and multiply to the detriment of his neighbours. The author's view is that 'owners should at least have to pay some additional tax for keeping such areas unproductive, or they should be obliged to replant them properly'. The views regarding amenity are bluntly expressed and expose some of the false values current in the estimation of forest beauty. The fact that we are not yet a 'forest minded' people may be deplorable, but until forests grow up and can be seen and fully appreciated both from the aesthetic point of view and from that of utility, it is hopeless to expect any but the interested minority to become enthusiastic. Truly foresters 'have a great duty to perform in preserving the beauty and general amenities of our woods'.

It is a most difficult task in this country to square the circle of sport and forestry. Mr. Ackers makes a gallant attempt; he postulates that economic conditions change and progress should not be hindered, but the plain fact is that the provisions of the forest working plan and the views of the gamekeeper can seldom be completely in accord. The only *modus vivendi* on a sporting estate is goodwill all round, the result of which must always leave an imprint on the woods more or less plain to see. In this book, working plans are relegated to a little over a single page, although it must be remembered that the preparation of, and adherence to, a working plan could yet save many a British woodland. After all, a working plan, in its essentials, is only a record of intentions of a programme of work to be done over the period covered; the plan need not be fearsome in any respect and its construction is not the difficult and complicated

affair it is so often made out to be. As Lord Clinton says in his Foreword, where an owner 'employs foresters and a woodland staff sufficiently trained to apply modern methods to the production of timber . . . the results are seldom unsatisfactory'.

Recent Books on Timber and its Treatment.

(1) *Timber, Its Structure and Properties.* By H. E. Desch. Macmillan & Co., Ltd., London, 1938. Pp. 169, 90 illustrations. Price 12*s.* 6*d.*

(1) *Timber Drying and the Behaviour of Seasoned Timber in Use.* By R. G. Bateson. Crosby Lockwood & Son, Ltd., London, 1938. Pp. 138, 28 illustrations. Price 10*s.* 6*d.*

(3) *Wood Preservation.* By George M. Hunt and George A. Garratt. McGraw-Hill Book Company, Inc., New York and London, 1938. Pp. 457, 108 illustrations. Price 30*s.*

Reviews by B. J. Rendle

ONLY a few years ago there was an almost complete lack of scientific books on timber written by technical experts. At that time any one who seriously considered writing a text-book on timber technology must have been deterred by the fact that so many fundamental aspects of the subject remained to be investigated before certain basic principles could be established. The twentieth century, particularly during the post-war period, has seen the publication of innumerable papers and reports on the properties and treatment of timber. For various reasons these are not readily available to all whom they may concern, and it is desirable that their more important conclusions be collated in book form. The three books under review are attempts to meet demands by different sections of the public for technical information on timber.

(1) Mr. Desch has been impressed by the fact that much of the published information is written in language too technical for the non-scientific reader and is too widely distributed for easy reference. He has attempted the difficult task of writing a simple, concise account of timber technology for architects, surveyors, and building contractors who are interested in practical problems of timber utilization but are not in a position to study the original sources of information at first hand. There is certainly room for a book of this kind, and it is to be hoped that it will serve to lead many members of the timber-using industries to inquire more closely into those questions which particularly concern them. Those who are approaching the subject for the first time may be put off by the opening chapters on the structure of wood which are unnecessarily detailed and technical for a book of this kind. It is essential to know something of the structure of wood in order to understand its technical properties, but many of the microscopic features described in Chapters I to III have little or no bearing on the practical utilization of timber and are of no interest to the average architect, surveyor, or building contractor in search of useful information. The chapter describing the gross structural features of wood is much more practical and gives a good account of the way in which sapwood and heartwood, growth rings, grain, texture, &c., influence the properties and uses of timber. The basic physical properties of wood—weight, strength, moisture relations, and conductivity—are dealt with in a separate section. The chapter on strength properties is chiefly a description of standard methods of testing small clear specimens. Variation in moisture content and the changes which accompany it are expounded in an informative manner, and it is a pity that the chapter on seasoning is not made to follow on at this point instead of being placed in a later section of the

book. Defects in timber are classified as natural (growth) defects, those due to seasoning, fungi, and insects, and the succeeding chapter appropriately describes the principles and methods of preserving timber against fungus and insect pests and also fire and mechanical abrasion. The concluding chapter deals with the important subject of grading. The systems followed in Baltic countries and in the United States are described, and reference is also made to the Imperial Institute grading rules for Empire timbers.

The impression formed by reading this book is that the author is in closer touch with the scientific study of timber than with practical questions of utilization. Consequently the book is more suitable as a text for the serious student of architecture or building science than for the more mature member of the timber-using professions who has not had the advantage of a scientific training. The treatment is sketchy in parts, and there are several places where references might have been included to publications giving further particulars of technical processes.

(2) Mr. Bateson's book is a practical manual for timber users. The author's experience on the staff of the Forest Products Research Laboratory has given him ample opportunity of appreciating the drying problems confronting the timber industry in this country, and he is well qualified to advise on their solution. The book will appeal especially to those who have charge of seasoning operations. In the two chapters entitled 'The Air-Drying of Timber' and 'The Kiln-Seasoning of Timber' they will find reasoned instructions for seasoning round and sawn timber of various sorts and sizes and on the methods of minimizing degrade, with descriptions of the principal types of drying kiln and their operation. There is also much to interest works managers, builders, and architects in the chapters on why seasoning is necessary, and what happens when timber dries. The manufacturer, mill-owner, or merchant who is inclined to erect his own kiln is catered for in a chapter on the construction and operation of a simple but efficient drying kiln designed at the Laboratory. Mention must also be made of a short but important chapter addressed to the 'small man' who does not handle timber in sufficient quantities to warrant the installation of a drying kiln, but who requires timber sufficiently seasoned for high-class interior woodwork. He is advised how to make use of a warm store for bringing air-seasoned timber down to 10 or 12 per cent. moisture-content, in which condition it may safely be used for the best class of construction without fear of subsequent shrinkage or warping. Finally, the chapter on the behaviour of seasoned timber after it has been put into service is of special interest to architects and others who use timber without being concerned in the actual drying of it.

In his introduction the author makes the categorical statement that for all practical purposes there is no difference between one piece of wood seasoned over a period of years and another identical piece dried in a few weeks. He goes so far as to emphasize that in his opinion seasoning and drying are synonymous terms. It is difficult to reconcile this attitude with recent research on log seasoning, which has shown that the starch in the sapwood of certain timbers is gradually depleted when these are left in the log for some time prior to drying, thus rendering the wood immune to attack by the *Lyctus* beetle. This is in fact briefly referred to on p. 21. One would have liked to see also some reference to the practice of water-seasoning which is commonly observed, not only in tropical countries but also at home, and is believed, rightly or wrongly, to have some beneficial effect on the timber. The absence of any precise pronouncement on whether the strength and other properties of timber can be permanently affected by injudicious kiln-drying or stoving suggests that this is another vexed question which remains to be answered.

(3) This is a book of the first importance to any one seriously interested in the practice of wood preservation or in the use of timber for structural work. It is intended to serve as a text for students in schools of forestry and engineering and as a reference volume for those engaged in the wood-preserving industry, for purchasing agents and engineers concerned with the use of wood, and for executives pursued by purveyors of questionable preservatives and processes. The authors are both well-known American timber experts. Mr. Hunt is in charge of the Section of Wood Preservation at the Madison Forest Products Laboratory, and Professor Garratt is on the staff of the Yale School of Forestry and is the author of more than one text-book on timber. There is no need to be an expert on wood preservation (and the reviewer has no claim to such a title) to see that the authors have carried out their task in an able manner. Such a comprehensive review of the very extensive literature on the subject will be widely welcomed. Probably its greatest value is for reference on the efficacy of different preservatives and methods of treatment, the best kind of treatment to adopt in particular circumstances, and the actual procedure involved in each case. But the book is much more than a summary of information. The authors evidently have a thorough command of their subject and have provided not only a clear exposition of the fundamental principles but also an authoritative opinion on many highly technical and controversial questions.

The agencies of deterioration in timber—principally fungi, insects, and marine borers—are dealt with in two early chapters. The discussion is confined to the most important of the organisms that attack timber after it has been put into service and are consequently susceptible to control through preservative treatment and the application of other preventive measures. As the book is intended for American readers pride of place among the insects is given to the termites, with shorter sections on powder-post beetles and carpenter ants. The death-watch beetle, furniture beetle, and *Hylotrupes*, which are comparatively unimportant in the States, are not mentioned.

The chapters on wood preservatives and wood-preserving processes cover a wide field of theory and practice. Readers of *Forestry* will be specially interested in the sections on preservatives and processes suitable for estate work. There is an interesting account of the various methods that have been devised for injecting preservatives (or dyes) into standing trees, on the principle that solutions entering the sapwood of living trees are carried in the sap stream for long distances. Despite the large number of different methods that have been tried, none of this type appears to have achieved commercial success, though it is suggested that they may sometimes be used with advantage in regions remote from treating plants, especially when suitable water-soluble preservatives are developed.

The discussion of the factors affecting penetration and absorption contains a good account of the anatomical structure of wood with reference to the remarkable variation in the resistance which different timbers offer to preservative treatment. This is essential to a proper understanding of what takes place when preservatives are injected into timber. Reference must also be made to the chapters on the economic aspects of the subject and on methods of protecting wood other than by standard preservative treatment, e.g. efficient seasoning practice, adequate ventilation of structural timbers in buildings, and the use of metal coverings as a protection against marine borers.

This book maintains the high standard of McGraw-Hill technical publications and will undoubtedly rank as a standard work. One suggestion for improvement is that the sub-headings of the chapters should be included in the Contents.

Studies on the Branch-suppression and Occlusion of Unpruned and Pruned Scots Pine. By Lars-Gunnar Romell. *Svenska Skogsvardsforeningens Tidskrift*, vol. xxxv, No. 4, 1937. (In Swedish with English summary.)

Review by W. H. Guillebaud

THE present contribution to the current literature on pruning deals with a part of the subject on which relatively little exact information exists, namely, branch suppression and branch wound occlusion. The length of time required for a pruned branch wound to occlude compared with the normal period of natural occlusion provides a good yardstick by which to estimate the probable results of pruning.

Romell discusses first the question of natural branch-shedding and occlusion. His observations show that in fully stocked pine stands the branches of trees in the upper canopy die in a regular and orderly manner, their length of life being determined by the age of the tree at the time the branch was formed. For example, a branch formed when the tree is 15 years old has an average length of life of about 8 years. Branches formed when the tree is 30 years old live for about 12 years, and those on a tree at 50 years old for nearly 24 years. The interval between the death of a branch and its fall, together with the healing of the resultant wound, was found to vary within such wide limits as 45 years and well over 100 years, averaging about 50 years in southern, 70 years in central, and over a 100 years in northern Sweden.

Romell then proceeds to analyse the results of his investigations on the occlusion of pruned branch-wounds—the whole of this work deals only with the pruning of dead branches. In the first place the period required for occlusion must be regarded statistically, the fact that a knot wound may occlude in as short a time as three years is of very little significance if, as often happens, on the other side of the tree there is a knot which does not heal over for 10 or 15 years, the true occlusion period is that required for the complete occlusion of practically all, say 99 per cent. of the knots, and when the data are examined in this way it is soon found that the occlusion period is never less than 12 years even with the most perfect pruning and may be as high as 20 years. A second conclusion is that the occlusion period must be divided into two stages, (1) the occlusion of the branch stub; in a properly pruned stem this is equal to the time required to form a layer of new wood which is as thick as the bark plus any swelling there may be at the base of the branch; (2) the time required for the occlusion of the branch base section; this is not merely a matter of forming a layer of new wood over the surface of the knot, because almost invariably in the healing of the branch wounds of Scots pine a peg of either bark or resin or both is included and occlusion is not complete until a continuous layer of wood is formed over the included peg. Romell has studied the relation between the resin or bark peg and the rate of growth of the tree and the size of the knot; he finds that the larger the knot and the faster the growth of the tree the longer this peg tends to be. As far as the first stage of occlusion is concerned the rate of occlusion is obviously a direct function of the rate of diameter growth, i.e. the width of the annual ring. The broader the ring the quicker is this stage of occlusion reached. In the second stage, however, the effect of greater ring width tends to cancel out against the contrary effect of rapid growth and larger knots in delaying occlusion owing to lengthening the included peg. In natural unthinned stands there is in fact very little positive correlation between rate of growth of the tree and period required for complete occlusion. In tended stands which are densely grown up to the moment of pruning and are then thinned out, it is probable that there is a positive correlation

between rate of growth and period of complete occlusion. Romell gives the following more or less empirical formula for determining the period of complete occlusion:

$$T = \frac{K+12}{1+b}$$

where T = the time in years, K = diameter of the largest knot in mm., and b = the width of the annual ring at the base of the branch in question (also in mm.).

As to the economics of pruning, when we compare the time required for complete occlusion after pruning (say 12–15 years) with the time required for the natural death of the branches and occlusion of the branch stubs (say 50–70 years) it seems evident that there must be a great gain from artificial pruning, but this is not enough in itself to make pruning a paying business. It is not the actual output of clean timber that counts but rather the difference between the sale value of the pruned timber as compared with the unpruned. On the basis of the time-difference between the occlusion of self-pruned wounds and artificially pruned wounds, one might conclude that pruning would be most profitable in the far north of Sweden, but Romell quotes an experienced forest officer as stating that the pine of a certain northern district is in much demand as a high quality product although the timber is full of small knots under half an inch in diameter. It is very doubtful if the value of this material would be appreciably increased as a result of artificial pruning. The economic outlook for pruning as a silvicultural measure can only be determined locally with due regard to the dimensions produced, the future market, and other factors.

The paper concludes with a brief reference to green pruning, but the writer appears to be unaware of the considerable amount of work which has been carried out on this question in Germany and has been summarized in Mayer-Wegelin's book on pruning (see Forestry XI (1), p. 59). Romell merely points out the virtual impossibility of reducing by dead-branch pruning the central knotty core to below 5 inches diameter, which he considers the critical value for the saw-mill industry, and emphasizes the improvement in this respect which might be attained if live-branch pruning were found to be practicable.

To the best of the present reviewer's knowledge the common occurrence of the resin (or bark) peg in occluded branch wounds of Scots pine has not been noted by other investigators on the dead-branch pruning of Scots pine. It is possible that it is a peculiarity of the Swedish pine.

The question as to how far the results obtained by Romell are applicable to British conditions is not an easy one to answer. On the one hand growth is, on the average, much faster in Britain than in Sweden, but on the other hand the Swedish pine has far finer branches. Mayer-Wegelin gives a diagram indicating for Scots pine occlusion periods ranging from 8 to 13 years, varying with the diameter of the knot, but any comparison with Romell's figures of 12 to 20 years is doubtful on account of uncertainty as to the use of the term 'occlusion'. Another factor which must also be taken into consideration is that Romell's investigations were carried out in natural unthinned stands.

German Forestry. By Franz Heske. Oxford University Press, 1938. Price 14*s*. net.

Review by the Editor

THIS book is the result of a desire of the Trustees of the Oberlaender Trust and members of the Carl Schurz Memorial Foundations, both of the United States of America, to make the experience of the German-speaking peoples in the field of

forestry available to the American people. The project was carefully prepared; in the first place Dr. Heske, who is a Professor at Tharandt, visited America in 1934, and in succeeding years American lumbermen and foresters visited Germany and Austria under his guidance, so as to acquaint him with their points of view. Dr. Heske is unusually well equipped to undertake this task. His wide knowledge of Central European forestry, particularly in the economic and management spheres, is already known to readers of this journal, because he contributed two articles on this subject to Volumes I and II of 'Forestry'. Moreover, unlike most German foresters, he has travelled widely, including visits to India and Africa.

In addition to a preface by Dr. Henry S. Graves, there is an introduction by Dr. R. B. Goodman, an American forest owner, who briefly, but informatively, reviews the present forestry position in the United States. The subject-matter of the book deals in an almost encyclopaedic manner with German forestry. The historical method is followed, and the emphasis is laid on the structure and development of the industry as a whole, and not on the details of technique. This is sound, because the principal contribution which one country can give to other countries is its philosophy rather than its practice.

The book is divided into two parts: Part I, German Forests and Forestry; and Part II, German Forest Policies. In the first part, the subjects dealt with are: land use; development of sustained-yield forestry; area, distribution, and composition of German forests; ownership; management of state, communal, and private forests; the sustained-yield structure of German forests; products and consumption of wood; methods of increasing yield; employment, and indirect benefits from forests. In the second part: forestry agencies; forestry science and education; recent German labour legislation in relation to forestry; tenure, rights, and adjustment of population to land; state restrictions on forest management; natural forestry legislation and development of forest taxation; forest fire insurance and credits and reserve funds; and the national afforestation programme.

The present area of forests in Germany (based on the 1927 census) is 35,140,000 acres, 27 per cent. of the land surface, made up of 19·2 per cent. conifer and 7·8 per cent. broad-leaved forest. Germany lost almost 4 million acres of forest, excluding colonial areas, through the Treaty of Versailles. Throughout the book losses in this way and their effects are emphasized. For example, it is stated that Germany lost 94 million acres of forest land in her pre-war colonies, and now has only 0·4 per cent. of the world's forest area, compared with 21 per cent. in the British Empire. Almost one half the area of German forests is in Prussia, over 18 million acres, but the highest percentage, according to land use, is in Baden, 39 per cent. It is interesting to note that 92 per cent. is high forest, and only 4 per cent. each is coppice-with-standards and coppice. During historical times there has been a definite change from mixed to pure stands and of broad-leaved trees to conifers. The present aim is to reverse this process. The distribution of size of individual forest in relation to ownership is interesting in connexion with the question of private forestry in Great Britain. Most of the state forests are moderately large, only 0·3 per cent. of them being under 250 acres, and 58·4 per cent. being 4,943 to 12,355 acres. On the other hand, in free, in contra-distinction to entailed, private forests 38·6 per cent. are 5 to 49 acres in extent, and 81·9 per cent. are under 1,235 acres. The present balance of ownership of forests is good: 32·4 per cent. state forests, 15·5 per cent. communal forests, 34·9 per cent. free private forests, and 12·9 per cent. entailed private forests, the remainder being owned by institutions associations, &c.

There are interesting chapters on the management of private forests and the development of state restrictions on forest management. The position varies from state to state in Germany, and the subject is dealt with historically. While the saying 'Gemeinnutz geht vor Eigennutz', that is, the public welfare takes precedence over the welfare of the individual, is taken as a text throughout the book, Dr. Heske considers that private forestry has a definite role to play. He wishes to avoid the extremes of *laissez-faire* on one hand and complete state regimentation on the other. In reconciling the demands of the individual and the society he wants 'not a compromise but an organic synthesis of the two elements'. In particular, he is against the regulation by the state of forestry technique, as this eventually kills all initiative and pride of ownership. Nevertheless, the improvement in the management of the free private forests, many of which are owned by farmers, is one of the present-day problems in Germany. On the basis of 1926–7, the yield of all timber per acre was: state forests, 72·9 cubic feet; communes, 62·9 cubic feet; restricted private forests, 65·8 cubic feet; and free private forests, 34·3 cubic feet. The low yield of the latter, which is still more marked if saw-timber only is taken, is attributed mainly to their small size and the difficulty of applying rational management.

Although silviculture and management are not discussed in detail, there are interesting sketches of their development in Germany. In order to make the country self-supporting, great efforts are being made to improve yields. At present 150 per cent. of the normal yield, i.e. a 50 per cent. increase, is being cut to meet internal requirements. This is only possible because of the conservative cutting policy followed during the last century and the resulting accumulation of growing stock. Even thus, however, it can only be a temporary measure, and must be reduced unless the productive capacity of the forests can be increased by improved silvicultural measures, hence the movement towards more broad-leaved species and uneven-aged forests from which improvement is expected.

There are numerous other subjects dealt with which are of interest both to the layman and the professional forester, such as the development of tenure of forest property, the taxation system, experience of fire insurance, financial returns, and employment. In the past we have suffered from importing forestry practices from Germany, often after they were discredited in that country by the more progressive element. We can, however, get much profit from the study of the history of German forestry, and the processes that have led to present ideas and philosophy.

The book is illustrated by diagrams and photographs. As it will also serve as a reference book a more detailed index would be an advantage. All concerned are to be heartily congratulated on its production.

Forstliche Versuche. XX. *Bodendeckung mit Pflanzenstoffen* (Use of Vegetable Refuse for Smothering the Natural Herbage in Checked Plantations). By L. Fabricius. *Forstwissenschaftliches Centralblatt*, vol. lx, No. 1, January 1938.

Review by W. H. Guillebaud

INTRODUCTION.

In the January number of the *Fortwissenschaftliches Centralblatt* Professor Fabricius gives an account of a series of experiments on the use of vegetable litter for covering the soil below planted trees. This is a practice which has been much discussed of recent years in Germany, the classic case being that of the private forest of Bärenthoren,

a Scots pine forest on a poor sandy soil in a low rainfall district not far from Berlin. For the past 50 years all the small lop and top has been left on the ground to the great improvement of the physical properties of the soil. Twig manuring (*Reisigdüngung* in German) has now become the mode, and Fabricius's experiments were intended to extend the method and endeavour to obtain some concrete evidence as to the results.

EXPERIMENTAL RESULTS.

I. The first experiment was carried out on a peculiar type of compacted silty soil in the Forstamt of Schwabach. The area in question consisted of a 3-year-old plantation of Scots pine and Norway spruce, which experience had shown was likely to remain in check for many years. The soil cover consisted mainly of heather, with subordinate Juncus, Molinia, and Carex. The following treatments were applied to duplicate plots:

(1) Control. No treatment.
(2) All vegetation screefed off and removed.
(3) All vegetation screefed off but left lying *in situ*. The heather and other plants removed from (2) were spaced uniformly over the surface of (3).
(4) All vegetation screefed off and left lying *in situ*. No further addition of vegetable matter.
(5) The surface was undisturbed, but heather and other vegetation cut in the vicinity was strewn thickly between the tree plants. Application was at the rate of 15 lb. of heather, &c., per square yard of plot.

Results. Method 5 (surface smothered with additional vegetation) has given outstanding results with both Scots pine and spruce. The pine responded to some extent in plots 2, 3, and 4, but the spruce only in 5.

After 8 growing seasons (age of trees 11 years) the development was as follows:

Average height of the five tallest trees in each pair of plots.

Method	*Scots pine*	*Norway spruce*
1	6 ft. 2 in.	3 ft. 0 in.
2	8 ft. 5 in.	3 ft. 1 in.
3	8 ft. 8 in.	3 ft. 8 in.
4	7 ft. 6 in.	2 ft. 11 in.
5	10 ft. 7 in.	8 ft. 3 in.

The experiment shows that it is unnecessary to screef or remove the heather from the soil. It is sufficient to cover the soil thickly with cut heather and other vegetation (Method 5) to bring about a very marked improvement in growth.

II. *Experiment on the smothering of herbage with spruce branches in the Forest of Grafrath, near Munich.*

The soil is of glacial origin and loamy in texture. The stand consisted of a 7-year-old Norway spruce plantation. This was divided into 8 plots each 16 yards square, of which 4 were untreated controls, the remaining 4 plots were covered with a layer of spruce branches in July 1928. In September of the same year the grass was found to be growing through the branches, and further material was applied which had the desired effect of completely suppressing the grass and other herbage.

The plots were measured at frequent intervals with the following result:

	Mean height of plants in feet at			
	1928	*1930*	*1933*	*1937*
Soil not covered (control)	2·1	3·9	7·7	10·8
Soil covered with spruce branches . .	2·2	4·1	9·0	13·0

The effect of the layer of spruce branches was slight during the first few years, but after 5 years a difference was fully apparent. Whether the difference of 2·2 feet in height at the end of 9 years is sufficient to justify the heavy cost is open to question. It may be remarked that according to British standards of rate of growth development has been decidedly slow. We should not regard a height of 2 feet in 7 years or 13 feet in 16 years as altogether satisfactory, although Fabricius remarks that the climate of the Grafrath Forest is optimum for spruce.

III. *Branch covering of two ash plantations in the Forstamt Neustadt.*

(*a*) *Compartment Dachsbau.* The ash were planted in the spring of 1928 in rows with natural seedlings from 8–12 feet in height in a moist hollow. The planting was on mounds. Plots were laid out and alternate plots covered to a depth of 18 to 20 inches with branches of Norway spruce (75 per cent.) and Scots pine (25 per cent.).

The plants made very little height growth during the first 3 years, but there was a slight improvement in favour of the treated plots. The girth increments showed a very marked trend which is summarized in the table below.

	Average (true) girth, inches	
Year	*Control*	*Treated plots*
1928	1·9	1·7
1931	2·4	3·6
1933	3·0	5·7
1937	4·2	6·9

The increase in the girth of the treated plots is very apparent from the above data.

(*b*) *Compartment Eichelgarten.* A similar experiment was carried out in the Compartment on ash of the same type and origin as in the previous compartment. At the end of three years the plants in the branch-covered plots were 25 per cent. taller than those in the untreated controls.

The increment in girth is given in the following table:

	Average (true) girth, inches	
Year	*Control*	*Treated plots*
1928	1·7	1·7
1931	2·9	4·7
1933	3·4	5·9
1937	4·5	7·5

The response to the branch covering has been very similar to that in Compartment Dachsbau.

In November 1932 the local forest officer reported as follows on these plots: The better development of the plants in the treated plots becomes more apparent every year; the foliage is more abundant and a darker green. The leaves remain longer on the twigs in the autumn; thus leaf activity is not only more intensive but also continues longer than on the uncovered plots.

SUMMARY AND CONCLUSIONS (Prof. Fabricius).

A layer of heather, conifer branches (and probably any other vegetable material) spread so thickly over the ground as to smother out completely the natural vegetation has had a very stimulating effect on the growth of the plantations. The effect is not merely temporary, but lasts over a considerable number of years and seems relatively independent of the species of tree and type of soil. Special investigations, in particular soil researches, are required to discover what are the factors responsible. Sometimes branch-covering fails to have any effect, a fact which also requires to be studied. There is also a certain amount of risk of damage by mice. The cost of the method depends entirely upon local conditions, i.e. upon the presence of sufficient supplies of covering material in the immediate neighbourhood; all that can be said is that it is bound to be considerable.

Weed growth, especially heather and branchwood from local fellings, cannot be better employed than for covering the soil in young plantations.

OBSERVATIONS.

The most interesting cases are those of the checked spruce in the first example and the two ash plots which responded so well to the branch covering. It is essential that the layer of imported branches and herbage shall be thick enough to smother out the vegetation below, which makes it a very expensive practice.

Report of the Chief of the Forest Service, 1937. United States Department of Agriculture. U.S. Government Printing Office, Washington, D.C., 1937.

Review by Barrington Moore

ANY one who does not realize the truth of the saying that a system of public forests is the backbone of forestry in any country will be surprised at the 1937 Report of the Chief of the U.S. Forest Service. While the activities of the Forest Service are reported, they are subordinated to a vigorous call for action in remedying the situation in private forests in order 'to avoid repetition of social and economic tragedies like those which have been widespread in forest regions generally'. He refers, of course, to the stranded communities, known as 'ghost towns', analogous to the special areas in Great Britain, left in many parts of the United States after the timber has been cut.

The Forest Service, since under Gifford Pinchot it took over the administration of the National Forests in 1905, has been the spearhead of the forestry movement in the United States, and now under a particularly forceful chief, Mr. F. A. Silcox, it is endeavouring to extend its leadership still farther in the field of private forestry. For this purpose a Division of State and Private Forestry has been set up in the Forest Service. The importance of privately owned forests is brought home by a short list of well-chosen facts and figures which show among other things that of all the potential forest growth, that is, potential increment based on site quality, nine-tenths is on privately owned land, and that of all forest products, 98 per cent. is cut from private

lands. The forest industries support 6 million people, and the farm woodlots help to support 2½ millions more. As the private forests are largely without forest management, private ownership holds the key to the forest situation.

Undoubtedly there has been a good deal of improvement over the old destructive methods which allowed fires to follow cutting, and thus destroyed reproduction especially in coniferous forests, leaving the land a barren waste. More operations leave some young growth and the possibility of a future forest. But this does not mean sustained yield, and without it the hiatus between the removal of the present timber and the maturity of the next crop brings about the hardships of 'ghost towns' with all their attendant evils, hence the emphasis on sustained yield. To remedy the situation a three-point programme is proposed, and presented in bold-face type as the outstanding feature of the report. The points are: first, to increase the proportion of publicly owned forests; second, continued and extended public co-operation with private owners; and third, public regulation of private forests.

Increased public ownership, both by the Federal Government and the States, requires purchasing the land, because, unlike Canada which kept the title to the land while disposing of the timber, the United States allowed both land and timber to pass into private hands. He suggests from 125 to 150 million acres, of which about 50 million should be acquired by the States. This would leave 270 million acres of the best forest land still in private ownership. The National Forest Reservation Commission, charged with the purchase of forest lands for the Federal Government, recommends in its last report the acquisition of about the area suggested. The cost would be around $700,000,000, or £140,000,000, a sum which will not easily be found, with the heavy legacy of debt left by spending for recovery from the depression. Co-operation with private owners, through the States by means of subsidies matched by State funds, is already protecting a great deal of private land. However, some private owners, already paying a considerable proportion of the cost of protecting their lands, complain that the public, as it starts most of the fires, should carry a larger part of the cost of protection. Until the public does its part, they say, it has no right to insist on their doing theirs. There is some justification for this in the rather niggardly appropriations, but it can easily be used as a screen to cover neglect of reasonable measures for perpetuating the forest.

The recommendation for public regulation of private forests, as would be expected, has overshadowed the other two, and has aroused strong opposition among timberland owners. The reasons given for public regulation, namely, stability of labour and of the industry and protection of owners practising forest management against those exploiting ruthlessly, are sound and rather generally accepted. But the proposal comes at a time when there is a good deal of feeling against the interference of Government in business. That it could be done and would eventually be supported by the industry must be admitted by any one who witnessed the early opposition of the lumbermen to the methods of cutting on Forest Service timber sales, opposition which was overcome as the lumbermen became accustomed to these methods and understood the reasons for them. The functions of the States in the general scheme of government offer a problem peculiar to the United States, but could probably be worked out along co-operative lines analogous to the present Federal State co-operation in fire protection. At any rate, it is not unlikely that the prospect of public regulation may induce some forest owners who hitherto have thought of forestry only in a casual sort of way to study more seriously the application of forest management to their lands. A further example of leadership in forestry on private lands is a friendly warning against over-exploitation

in the southern pine forests, brought forth by the very rapid expansion of the pulp industry there since the discovery that paper pulp can be made from southern pines. Although the American Pulpwood Association has suggested rules to prevent the suicidal practice of clear-cutting immature stands, there are extensive areas in the south where already existing industries are using more wood than is replaced by growth.

The activities of the Forest Service in administering the National Forests, which now comprise 171,403,306 acres net, and other work, such as research, and co-operation with states and private owners, are concisely reported. In protection against fire the highly developed technique has resulted in holding down the area burned to 0·8 acre per thousand, the best record yet attained, and that in spite of unfavourable conditions. Subjects which have received increasing attention are wild life management and recreation.

The form of the report has been improved by the inclusion of a detailed table of contents and the use of larger type for the first eight pages, though the rest of the report is in the same small type. The tables have all been placed together at the end in an appendix.

Erosion and Soil Conservation. By G. V. Jacks and R. O. Whyte. Technical Communication No. 36, Imperial Bureau of Soil Science, Harpenden, Herts. 1938. Price 5*s*.

Review by the Editor

THE subject of erosion is receiving increasing attention in many parts of the world and this publication brings together available information from most regions except South America. The information has been compiled, partly from published data, and partly from reports received from correspondents of the bureau. This communication deals with the current state of affairs rather than with methods of combating them; it is designed to give a picture of the position. It is of immediate interest to agriculturists and forest officers, but there is much of interest to members of the general public. As an informed public opinion is a necessary step to adequate corrective measures, and the British race is responsible for the government of enormous tracks where the problem is acute, the publication is commended to all.

Wind erosion is serious in the prairie provinces of Canada, but in most instances erosion by water is more serious, hence nature of soil, degree of slope, and amount and distribution of rainfall are all important. The most fruitful cause of erosion is deforestation. The classical instance is the Mediterranean, but this cause is world-wide. Shifting cultivation has also had its effect, while over-grazing, due to many causes, has done much damage, particularly in India and Africa. Particular crops and methods of cultivation are a precursor of erosion. Extensive cultivation generally, through mechanization, e.g. in the United States, is a danger, and in this connexion Russia is vigilant. There the importance of grass as a protective covering is being stressed. North-western Europe's comparative immunity to erosion has been attributed to the fact that wide-spaced crops, such as maize, cotton, and tobacco, are not cultivated. Clean cultivation of tea and rubber in Ceylon and Malaya has been associated with erosion, while in Siam the more neglected plantations have escaped. Although man has generally been the cause of erosion, the locust plagues in Kenya, and rodents in the Tibetan plateau region have been contributary factors.

The excellent work which has been carried out in Japan since 1683 is described.

Up to ten times the value of the land in hill regions has been spent on works to protect the valleys. Although the position is serious in China, the system of terraces for rice cultivation from early times has been beneficial.

Considerable space is devoted to the United States of America where erosion is so serious, and where much has been done in surveying land and carrying out research. There the forest services have played an important part.

Scottish Pit-Props. National Home Grown Timber Council, Bulletin No. 1, 1937. Price 1*s*.

Review by the Editor

SINCE the War, when large quantities of pit-props were supplied from Scottish woodlands, the level of prices has been such that it was not economic to do so from centres more than about 50 miles from collieries. This has been the principal reason for the neglect of thinning which has caused increased concern. An experiment was begun by the Scottish Committee of the National Home Grown Timber Council in 1936 to obtain data on costs of production and relevant matters. This bulletin presents the results; it was published at an opportune time, because the rise in pitwood prices which took place in the summer of 1937 has led to activity in thinning and pitwood preparations, and the data has been of considerable value to owners and others concerned.

The experiment was carried out at five centres: Invermay, Perthshire; Crathes, Kincardineshire; Glendye, Kincardineshire; Alltcailleach, Aberdeenshire; and Strathspey, Inverness-shire. It was a co-operative effort, owners providing the woods and timber merchants carrying out the preparation of the material. For each centre a silvicultural description of the wood and a complete statement of the produce with itemized cost of preparation and return from sales are given.

In each instance the species was Scots pine, and the age varied from 27 to 55 years. The total area thinned was 171 acres, which produced 36,001 trees, giving 50,224 cubic feet (Q.G.), an average per tree of 1·4 cubic feet; 39,718 cubic feet of props were cut from the total, an outturn of 79 per cent., and 232 cubic feet per acre. The woods had either not previously been thinned, or had not been thinned for a considerable period, and were all overstocked. This explains the relatively high outturn per acre. Of the cost of production at the collieries, £540 went on railway carriage, and £938 in direct wages; the latter represents £5 9*s*. per acre. The experiment showed that with the prices prevailing at the time—the price obtained averaged 11½*d*. per cubic foot delivered—the receipts about balanced expenditure, leaving nothing for the timber. Since that time the price of props has practically doubled, and while railway rates have advanced 5 per cent., and wages much more, pit-prop production is at present profitable under most conditions. In some instances, unfortunately, this has had an adverse effect on the general forest position, namely, the clear-cutting of immature plantations and over-thinning. The net advantage, therefore, of the present level of prices is not so high as it should be.

A number of interesting points emerged, such as the importance of the provision of stacking grounds in laying out plantations, the importance of a good standard of preparation, and the need for developing methods to utilize the waste material.

There are numerous good photographs illustrating stages of preparation, and the Council are to be congratulated on an interesting and useful publication.

A Contribution to Our Knowledge of the Injuries caused to Silver Fir by Plant-lice. By Dr. Helene Francke-Grosmann. *Tharandt Forstliche Jahrb.* lxxxviii. 1050–82, 1937. (In German, with summary.)

Review by R. Neil Chrystal

ONE of the most important problems which foresters have had to face during the past thirty years in those parts of central Europe where the Silver fir (*abies alba* Miller) is grown is the so-called 'Tannensterben', or dying back, which occurs on trees of all ages, and on many different types of soil. Here in Britain we also have had trouble in raising young crops of Silver fir, and the death of the young trees was always attributed to the work of the plant-louse *Adelges nüsslini* Börner, one of the group known to the forester as Chermes. Similar instances of young Silver fir being killed by its attacks are known from Denmark, where the extent of the damage was so serious that systematic spraying was successfully carried out and many plantations saved. Investigations on the same insect have also been carried out by workers in Switzerland.

In the paper under review the author, Dr. Helene Francke-Grosmann, has not confined her studies to the *Adelges* species, but also includes the plant-lice *Mindarus abietinus* and *Lachnus pichtae* Mordw, both species which are recorded as being associated with Silver fir suffering from 'die-back'. Her material was collected from a wide area which embraced such well-known Silver fir districts as the Black Forest, the Riesengebirge, and the Erzgebirge.

The major portion of the paper deals with the *Adelges* species for which she has retained Börner's old generic name of *Dreyfusia*, which we shall adopt here. Dealing in the first place with specific distinctions, the author considers that the *Dreyfusia* species should be divided into three, e.g. *D. piceae*, a form which prefers the older main stem, *D. nordmannianae* and *D. Schneideri*, both of which are found on the younger branches and twigs. The author is inclined to consider these two as being of the nature of biological races, since the characters separating them are difficult, and can only be recognized by expert microscopical examination.

Some twelve years ago the writer of this review made a microscopical study of the tissues of the Silver fir injured by the *Adelges*, and found that serious interference with the conducting tissues took place owing to the substitution of abnormal tissues for the normal xylem-conducting elements. Dr. Francke-Grosmann has followed up and extended these studies in this paper, and the bulk of the text deals with these. Such information is given concerning the different parts of the plant tissues from which nutritive materials are drawn. In this connexion the author distinguishes the albuminous secretion which composes the so-called 'bristle-sheath' which remains in the tissues to show where the stylets have been probing in search of food material; and a hypothetical secretory fluid, containing powerful enzymes, which has strong digestive properties. The presence of this secretion has still to be clearly demonstrated, but the author considers that the effects produced on the tissues cannot be due to the action of an albuminous secretion alone.

The Silver firs evidently vary greatly in susceptibility to attack, and in some regions, notably the Riesengebirge, there would seem to be a resistant strain present. In the Schwarzwald the Silver fir is very susceptible, and the author suggests that an experiment might be tried of bringing some of the fir from the former locality and trying them out in the latter situation.

When all is said and done, however, it would seem that this 'Tannensterben' is a condition produced by a variety of factors not easily disentangled from one another,

of which the *Adelges* only form a small part. The author gives clear cases where the susceptibility of the fir to attack is obviously conditioned by external factors, rate of growth, abundance of light, drought, &c., being among those listed, while she also states that in the case of Silver fir growing near industrial districts where smoke damage is prevalent, the effects of *Adelges* attack are still more marked.

The paper is well illustrated, and clearly written, and cannot fail to be a valuable addition to the study of this most perplexing problem.

How to make Forestry Pay. By the Hon. Richard Coke. W. Heffer & Sons, Ltd., Cambridge, 1938. Price 1*s*.

Review by the Editor

BRITISH forestry already owes a debt of gratitude to Major Coke. He has shown at Weasenham that a small forestry estate, in this instance less than 200 acres of woodland, can be made not only intensively interesting silviculturally but also profitable, provided the owner has the necessary interest and skill. Secondly, Major Coke is the pioneer in this country of uneven-aged woods without clear felling; his system is what is sometimes termed *Waldgärtnerei*, selection system intensively applied. Weasenham was visited by this Society in 1936 and the woods described in *Forestry*, x (2), pp. 153–5.

This booklet presents its author's views on how British forestry can be made more profitable. Briefly they are the strict control of rabbits, securing continuity of management, the wider use of methods of natural regeneration where there are existing woods, the elimination of clear felling, and due attention to thinning. His whole philosophy would have the support of most of the leading foresters on the continent, and there is no doubt that it has considerable application in this country. Nevertheless, it must be recognized that natural regeneration is easier to secure on the light soils at Weasenham than in some other parts of the country.

NOTICES

The Imperial Forestry Institute, University of Oxford. Thirteenth Annual Report.

IT is stated that there was a good attendance of officers taking refresher courses, and a number of lectures were given by them on a variety of topics, principally erosion. Extended reference is made to the Institute's first tour to Finland, and to the bearing of forestry work and research there to forestry problems both under tropical and temperate conditions. It is not stated, however, whether it is being made the regular general tour for Institute students to the exclusion of Central Europe. As usual the research and other work carried out by the different sections is described and a list of publications by members of the Staff given.

Circular Saws. Forest Products Research Records, No. 22. H.M. Stationery Office, 1938. Price 6*d*.

THIS is a useful publication, written by Mr. P. Harris. Particular attention is directed to the parts and angle of teeth and to cutting speed. The pitch, gullet shape and size, hook, clearance, bevels, and set are dealt with and the text suitably illustrated.

The Preservative Treatment of Building Timber. By R. C. B. Gardner. The British Wood Preserving Association Circular No. 2. 1937. Price 6*d*.

THIS publication deals in a simple and easily understood way with the causes of decay in timber and methods of minimizing it. Fungal and insect attacks are described and diagnostic features given. Then follows a short description of methods of preservative treatment, including various methods of creosote treatment, and the use of water-soluble salts, solvent-type preservatives, paints, and varnishes. Reference is also made to fire-proofing of timber. The use of treated timber in building construction is then discussed. In appendices, a short description is given of the principal fungi and insects attacking timber, together with a list of further publications on the subject of the circular.

This publication should be useful both to the general public and to building contractors.

Progress of Forestry in India during the past Twenty-five Years. By H. G. Champion. The Indian Science Congress Association. 1938.

THIS is a short but interesting summary of the progress made during the past quarter of a century, which it is stated is greater than at any previous period. It is included in a publication 'Progress of Science in India during the past twenty-five years'. The subjects dealt with are: forest education, organization of research, research in regeneration problems, tending, protection, silvicultural systems, working plans, and utilization. In addition a selected bibliography is given. Although each section is quite short, and the whole article is only 20 pages long, the salient points of progress are given, and the paper will be of considerable interest to forest officers everywhere.

The Forest Resources of British Columbia. By F. D. MULHOLLAND. Department of Lands, British Columbia Forest Service. Victoria, B.C. 1937.

THIS is the second edition of a work first published in 1918 and which has since been the source of information regarding the forest resources of British Columbia. The following subjects are amongst those dealt with: topography, geology, and climate; forest types; trees of commercial importance; ownership of forest; forest resources; growth, depletion, and sustained yield, and insect damage. It is stated that there are still over 250,000 million board-feet of merchantable timber in the province, of which 110,000 million board-feet are accessible at present prices. The average annual cut during the last 10 years was 2,541 million board-feet. The principal problems to be faced are the reduction of fire-loss in the interior, and the partial failure of regeneration after logging on the coast region. There are numerous illustrations.

Enquête internationale sur la correction des torrents et sur la restauration des montagnes en Europe. International Institute of Agriculture, Rome. 1937.

THIS publication deals with the control of torrent waters and the restoration of mountain areas in the principal countries of Europe. The information has been obtained partly from the literature and partly from a questionnaire. There is an extensive bibliography and a series of photographs illustrating control works in different countries.

THE PROTECTION OF PLANTATIONS AGAINST FIRE

BY G. B. RYLE

(Divisional Officer, Forestry Commission)

INTRODUCTION.

THE literature on the subject of the protection of forests against fire is far less voluminous than that devoted to protection against animals and fungi. Although a financial assessment would be virtually impossible, it is certain that the world loss of growing timber through the ravages of fire must very closely approach that occasioned by pests, if it does not exceed it. In Britain the annual loss through fire damage is certainly vastly more serious than that caused by all the nursery and plantation pests and diseases combined.

In America a huge fire-fighting organization has been developed and a considerable amount has been published on the matter within recent years, but their problem—the protection of heavy timber forests and natural reserves—is totally different from the problem in the British state forests, which is mainly concerned with the preservation of unestablished and young thicket plantations. It is important to bear in mind, however, that Britain's young woods will some day become mature timber forests, and in planning and laying them out the lessons derived from the older forests in other countries may usefully be studied. The value of fire-lines and fire-belts in old woodlands is a particular case in point where the protection needs of the young plantation and the later needs of the developed forests may be of a completely different nature, and the necessity to foresee the latter at the time of planting is vital.

ORIGIN OF FOREST FIRES.

Apart from the possibility of fires originating from lightning, which is unlikely in this country, all conflagrations are directly man-made. The statistics collected by the Forestry Commission in respect of all fires which have occurred in the state forests show that 50 per cent. of fires originated definitely outside the forest boundaries, while 50 per cent. originated within the woods or from unspecified sources. It is unfortunate that the amount of damage done in each class is not stated as this would give a valuable indication as to the efficacy of the existing boundary control. Railway engines account for no less than 37 per cent. of the number of fires, but it is certain that the amount of damage from this source is not proportionately high as the risk is a known one in every instance and special precautions are taken. Road engines, with a 7 per cent. figure, are steadily becoming less important as the diesel type of internal-combustion engine replaces the old steam wagon. Foresters will welcome the day when the railway companies follow suit with a general scheme of

electrification. Thirty-three per cent. of plantation fires were caused by 'the general public', and this is the figure which really ranks in highest importance in view of its ubiquity. As long as the public has access to the forests or even to their roadside verges and footpaths the danger will be intense until a genuine forest sense is instilled into every child and perhaps even until boys cease to be boys! Incendiarism is feared and very commonly suspected during all seasons of drought in cases where there may have been any form of labour trouble or personal bitterness against the forest staff. Actually proved cases of incendiarism, however, amount only to 0·8 per cent. of the number of fires. Arson, intelligently planned, can of course so easily beat the most careful and elaborate fire-control system that to guard effectively against it is impossible.

TYPES OF FOREST FIRES.

Fire may occur in the ground vegetation, damaging the tree crop by scorching the bark and killing the cambium. In old woodlands where the species are of thick barked types this surface fire may cause little damage, although if of common occurrence it will gradually impoverish the soil and will of course prevent natural regeneration. In young crops, however, and amongst species of thin bark such as beech or spruce, the damage is often severe, while in unestablished or young thicket woods the result is generally fatal. Crown fires, which of course normally start from surface fires, are commonest in thicket coniferous plantations which bear beneath the live canopy a considerable accumulation of dead unbrashed lower branchwood, suppressed trees, and weed rubbish. The danger lessens after the first thinnings have been made, the forest floor becomes cleaner, and the crowns higher above the ground. In the case of broad-leaf species or larches in moderate-sized blocks, the crown-fire risk from this stage of development onwards is negligible. A crown fire rushing through a block of pine or spruce may become so fierce, however, as to be able to traverse a width of several chains of less inflammable broadleaf canopy. Surface fires traversing dried peaty or deep humose soils may ignite the vegetable content of the soil to cause a ground fire. Such fires burn slowly but are most difficult to extinguish, and they are troublesome because they may suddenly burst into flame on the surface, to start a fresh outbreak in the vegetation. Ground fires are most liable to occur in dry *Calluna* or *Erica* peats and occasionally in well-drained *Molinia* areas.

In considering young plantations, the surface fire and the crown fire cannot be differentiated, and it will be useful here to consider the matter as it is affected by different classes of natural ground herbage commonly occurring upon afforestation areas. *Molinia* fires should take first place in view of their rapidity, and also because such extensive tracts of land with a *Molinia*-dominant vegetation are now being brought under forest crops by the Forestry Commissioners. When allowed to grow without interference from the grazing of sheep as must necessarily be the case in young plantations, *Molinia* becomes annually stronger in its development and after two seasons of growth the grass assumes an extremely rank, quasi-tufted formation. In winter the whole of

the foliage dies, becomes loose, and liable to blow into any small sheltered hollows; in dry weather it quickly becomes intensely inflammable. Its loose blowing character renders both fire protection and fire-fighting extremely difficult. Artificially cultivated fire-lines may become smothered over with blown, dry grass in the course of a single day of gusty weather. Controlled burning is a hazardous operation on any but dead calm days, because the light burning fronds of grass are so easily whisked up into the air by the slightest breeze, to drop down again still burning perhaps many yards away. In the moister climates of the north and west of England where the *Molinia* country predominates, the number of really calm days when conditions are suitable for the fairly safe burning of fire traces are normally totally inadequate for the conduct of any large-scale programme of protective works.

For the same reason fire-fighting in *Molinia* country is difficult in the extreme. Favoured by a fair wind, a serious fire which occurred at Margam Forest, Glamorganshire, several years ago advanced half a mile in seven minutes, and mats of burning grass were carried for many yards in front of the flames. The fire danger in *Molinia* is entirely confined to the winter seasons and reaches its climax in the first three months of the year. While the course of a fire is rapid, the conflagration nearly always has a very clearly defined formation, advancing quickly before the wind, but leaving a slow burning line at the sides and the leeward edges. As these fires occur in the winter, it is common for the surface of the grass to be bone-dry while the lower layers are still wet. The quick fire leaves the moist bottom herbage unburned and a continuance of dry weather will soon dry this, so that a second fire may easily follow over the same ground within a few days.

Bracken fires, like those in *Molinia*, are mostly to be feared in the late winter and early spring when the previous year's herbage has died and become desiccated and flattened by the winter's rain, frost, and snow. Dead bracken is not so liable to blow about, however, so that a well-formed fire-line cleaned up in the autumn will generally remain in a tolerably safe condition throughout the winter months. A secondary fire-danger season occurs on bracken ground in the hot summer weather when the residue of plantation weedings, drifted between the rows of young trees, becomes thoroughly dried. This danger period is most serious in districts favoured by a holiday-making public or adjacent to public ways. Owing to the rapid re-growth of green herbage on any exposed portions of the ground not smothered by the cut bracken, this danger is not normally either intense or of long duration.

A bracken fire is less regular in its progress than is the case with *Molinia*, owing to the heavy deposit of dry crumbly humus which occurs, and the greater variety in height and density of the growth. The smouldering humus, not easily visible in daylight, constitutes an added hazard as it may burst into flame again long after the main conflagration has passed. Bracken fires do not as a rule throw up burning embers and sparks to a serious extent, but the height of the flames in rank places, especially in a well-grown young plantation, may give rise to crown fires.

Heather fires (*Calluna* or *Erica cinerea*) may occur at any dry season of the year because the foliage of the heaths is readily combustible both in the live and the dead state. This type of herbage burns more slowly than *Molinia* or bracken, and the drift of sparks is negligible. The tough wiry stems of tall *Calluna* are resistant to the action of fire beaters, however, and make fighting less easy. The occurrence of summer heath fires, at a season when the soil or peat, which generally exists beneath a dense ericaceous herbage, is very dry commonly results in a smouldering ground-fire difficult to extinguish without copious water. Cultivated fire-lines through heather types are easily formed by ploughing, and with a modicum of tillage will maintain their efficacy for two or even three years without further expenditure.

Gorse (*Ulex*) in dense growth throughout a young plantation constitutes a risk even greater than *Molinia*, but fortunately seldom occurs over such extensive areas. The risk increases steadily with the age of the tree crop, and reaches its maximum in the pre-thicket stage when normal weeding operations cease, and when there may be a dense undercrop of gorse only a few feet less in height than the young trees. Under such circumstances it is obvious that fire-fighting becomes a hazardous task as access within the wood is difficult or impossible. The gorse fire-risk is not seasonal, but arises at any dry period. Fire-lines through gorse areas may be maintained at reasonable cost by annual mowing, burning the refuse in a narrow strip in the centre of the ride, or by ploughing with periodical cultivation thereafter. At dangerous places, especially beside public ways, the gorse should be kept cut short beneath the young trees for several yards on either side of the main ride, and so maintained until the woodland canopy is adequate to smother the growth. Broom (*Cytisus*) is similar to gorse in all respects, but is less inflammable.

Grass fires, other than *Molinia*, are the easiest of all to control, although the rate of burning, if there is much of a breeze blowing, may be rapid. The danger seasons are in late winter or very early spring, where there may exist a rank matted growth of ungrazed old pasture grass. A severe drought accompanied by heat in midsummer may bring about another danger season. The formation of fire-lines in grassland is done most safely by ploughing and subsequent cultivation. Mowing and burning are moderately safe methods, but are less secure against a summer drought fire, and in the long run are little cheaper.

FIRE-PREVENTIVE MEASURES.

Given an enlightened public, the fire risk in Britain could be made quite unimportant and could be almost confined to the adequate safeguarding of railway lines where they traverse the forests or run through inflammable herbage types in the vicinity thereof. Education then should be the first step of a purely preventive measure. To be effective this requires to be done on a national scale, backed up by an intense local propaganda at each important forest district. The wireless broadcast, the press, and the cinema could all be brought into use in a way to arouse the interest of the public. The court room

could be of value in exposing the folly and criminality of careless or wanton fire lighting, but before this can be done with any degree of success the law of the country needs to be considerably amplified. The present weakness lies in the fact that a conviction cannot be secured against a fire-lighter unless malice can be proved: gross carelessness is no crime where a forest fire is concerned.

Local education of the public in the neighbourhood of large forests can take place through the medium of the schools, the scout and guide movements, hikers' associations, village clubs, and other organized bodies. In these days of long-distance motoring and cycling, however, it is not easy to obtain adequate contact with all of the members of the public which may visit the forests. For the non-resident forest visitors carefully worded notice-boards and tactful patrols become necessary, and the layout of the forest itself, with its network of fire rides and its dumps of fire-fighting equipment, should serve as a means of indicating that fire danger is real and important. Whether or no it may be a wise policy to prohibit the entry of the public into the forests altogether must depend entirely on the local conditions. Where people have for a long period been in the habit of enjoying a more or less unrestricted entry on to certain areas, it might well be imprudent suddenly to curtail their enjoyment by a total prohibition of passage or entry. Of course indiscriminate trespass, whether or no accompanied by the commission of any actual damage, must be rigorously prevented, and any regulations as to smoking or lighting picnic fires must be stringently enforced.

In certain districts the picking of bilberries (*Vaccinium myrtillus*) by the local populace had been enjoyed for a long time without hindrance, and on enclosure of these areas for afforestation there arose a feeling of considerable dissatisfaction when this privilege was stopped. It was decided to issue permit tickets at a cost of 2*d*. each under a system of simple regulations. By this means all the local inhabitants retained their privilege at no material cost, and for their part they jealously guarded their preserve against the trespass of unauthorized interlopers. Any privileges granted to the public or to sections thereof should be withdrawn immediately after the occurrence of any abuse which results in fire damage, and similarly a fire occurring in the vicinity of a favourite picnic or similar places may usefully be made known to the public through the press to illustrate the vileness of some one's folly or carelessness.

Where railway lines pass through forest areas, a code of clear working arrangements should be drawn up in collaboration with the local officials of the railway company with the approval of the company's head-quarters. It will then be the forester's duty to ensure that this code is adhered to and at once to report any infringements which may occur. Unnecessary stoking of engines, leading to the blowing out of glowing cinders and the dumping of hot ashes on the permanent way, are special points to be watched for.

In hunting districts an occasional word with the master will suffice to ensure careful behaviour on the part of the hunt. In this respect, if in few others, the huntsman and the forester will be of one mind.

LAYOUT OF THE FOREST IN RELATION TO FIRE PROTECTION.

It is in regard to the planning of a new forest area to obtain the maximum of safety from fire that the forester needs to keep the distant future in mind to a high degree. The fire-protection system which may be best suited to the forest in its infant stages may not necessarily hold good when the tree crop is fully grown, and it is thus important to make full allowance for the future when first laying out the various plantations. Fire-lines or rides which are permanently maintained in a condition to check the passage of ground fires, or in an emergency to form safe strips from which to light counter fires, are of prime importance in a young forest, but become less and less useful as the woods develop in height and form a canopy. Fire-belts or strips of plantation of a dense crowned uninflammable type are of major service in older conifer woods and are completely valueless in the young pre-canopy stage of the forest. Access to all parts of the forest from the main centres of habitation or from public roads may be easy in young plantations before the branches become interwoven, but can only be permanently secured by a thoroughly adequate network of rides, paths, and roads. Long-distance visibility may similarly become obscured as the woods grow in height, unless carefully planned observation stations are scattered on the hill-tops and left unplanted for a sufficient distance around them.

The formation and maintenance of fire-lines is an item of considerable expense, and their layout and extent need to be governed carefully in accordance with the actual degree of fire risk on the forest. Internal rides of any reasonable type or width will never in themselves be sufficient to prevent the passage of fiercely burning fire advancing before a stiff breeze; their chief utility is in forming a check line from which to fight or in emergency to counter-fire. In sheltered positions, however, or in instances where the fire-lines are situated at an oblique angle to the direction of advance of the fire, they may have a more positive controlling value. Thus the general policy where possible should be to form the main fire-lines in places where an advancing fire may be expected to become naturally somewhat lulled on reaching a sheltered position out of the force of the wind. Fire-lines formed to run up and down hill-slopes should thus be placed well to one side of exposed bluffs. On long hill-slopes the rush of fire uphill might render any system of contour fire-lines of little value, but vertical rides would more easily check any tendency of the fire to spread out sideways as it advanced to the crest. More horizontal fire-lines might then be effective at the brow of the hill just under the extreme crest, where the degree of slope has flattened off to some extent.

The steeply graded railway line meandering up the bottom of a mountainous forest valley is as awkward a menace as any. It can only be made moderately safe by means of a combination of fire-line and fast-growing fire-belt alongside the track, together with a closely spaced series of uphill fire-lines designed to part the slopes into a number of vertical blocks. Special danger zones, such as upland *Molinia* flats or favourite picnic sites, may advisably be girdled by effective fire-lines.

There are several methods of formation and maintenance of fire-lines, each of which is serviceable under proper conditions. The cultivation of the soil, resulting in the complete removal or burial of all inflammable herbage, is undoubtedly the best and safest method, and where mechanical power is available it may also be the cheapest. On reasonably flat ground, not too heavily encumbered by stumps or rocks, ploughing by tractor or horse-power will serve to turn in the vegetation and to bring up a good soil or peaty surface. Where the soil is of a fairly easy working nature, the further tillage of this type of line may be confined to simple drag harrowing or rolling, and it will be maintained in a clean condition by periodical dragging and less frequent ploughing. On deeper peat soils, such as commonly occur on heath or *Molinia* moors, the cultivation of the roughly ploughed strips is less easy, but excellent results have been obtained on the most difficult of tufted *Molinia* types by the use of a heavy double-disk harrow. On wet peaty areas it may be mentioned in passing that the fire-lines should be well drained in order to facilitate the tillage and gradual improvement of the cultivated surface. On ground too steep or too liberally interspersed with boulders or stumps, where ploughing is out of the question, the alternative of hand cultivation may become an expensive necessity. The cost, however, is considerable, and this class of work should be reduced to the minimum. The modern track-laying tractor has opened up the scope of ploughing to an enormous extent within recent years, and there is no doubt that the present conservative attitude prevalent in this country towards mechanization in rural operations will shortly give way to a realization of a truer economy in the matter. The ploughed fire-line is more effective, more easily maintained, and can be formed with more absolute safety than any other type. The cultivated fire-line may be made over the whole width of a broad fire-break, covering a ride of some 30 feet or more in width, or alternatively the cultivation may be limited to two comparatively narrow strips, one near to each side of the ride. The intervening central band in the latter case is then commonly made safe either by direct burning of the herbage or by cutting with a scythe and burning in small heaps. Where ploughing is practised the complete cultivation of the whole required width is obviously the safer course.

Mown fire-lines are cheap to form and maintain, but are definitely inferior in their safety value to other types. On bracken land, where ploughing for any reason is impracticable, a mown fire-line can be made reasonably safe in the course of a few years. If done in the early summer repeated cutting of the bracken weakens the growth and encourages the development of grasses. Grass or heather rides are improved by regular mowing and tend to become well clad with a non-inflammable greensward. Gorse may be similarly kept in control by annual mowing to obtain a reasonably safe fire-break. Mown rides are normally kept clean by means of a hand-scythe of the type used for agricultural purposes, but with tough herbage of the heather or gorse types a shorter briar scythe is required. A small motor-driven reciprocating scythe has recently been put on the market and has proved itself to be admirably suited for ride-cutting purposes, even on very steep slopes and

amongst rough herbage. Travelling at a slow walking pace it cuts a 3-foot sward and is able to mow through woody material such as thick old heather or 4-year-old gorse stems without undue strain on the small two-stroke engine. After mowing the fire-rides it is of course necessary to remove the cut herbage, and this is generally done by collecting together and burning in small heaps under careful control or simply by dragging the refuse well back into the young plantation where it can rot away between the trees.

The burning of fire-lines can normally be done only in combination with narrow screefs or plough strips or with mowing. It is a method of formation which will give a good break of any desired width at reasonable cost if suitable weather conditions occur at the required season. It is, however, essentially a task of some risk and should never be conducted excepting under the direct supervision of a really competent man who has had several seasons of previous experience. The golden rules of ride-burning may be summarized as follows:

1. An adequate gang of men must be engaged on the job, and more men should be working within earshot in readiness to give assistance.
2. All men must be supplied with the necessary equipment for fire-fighting in case the operation should get out of control.
3. Always burn from the top of a hill downwards; always burn against the wind; never burn at all if the wind be high or variable. Stop burning if the weather conditions become too dry or otherwise dangerous.
4. Water-packs should be kept filled and handy, but burning should be stopped if recourse has to be made to them frequently and repeatedly to prevent the fires jumping.
5. Extinguish all fires at least an hour before the end of the working day and ensure that every smouldering ember is extinguished before any of the gang leaves the spot.
6. Never try to hurry the rate of progress beyond the dictates of absolute safety.

Experiments have been tried to burn fire-lines without the previous cultivation or trimming of safety margins by the use of small portable corrugated metal 'walls', but the results have not justified continuance under any ordinary large-scale conditions. Another 'safe' method of fire-line burning has been tried with limited success by scorching the vegetation when it is in a moist or green condition by means of a powerful type of blow-lamp. It has been claimed that in damp *Aira* and *Agrostis* it is possible to scorch a 4-foot strip two miles in length in a working day. It has been difficult, however, to get the work on a practical basis as excessive moisture renders the progress uneconomically slow, while a greater degree of desiccation makes the work dangerous and difficult to control.

The scorching method is useless in *Molinia* or other very rank types of herbage, because in this case if the surface of the material is damp enough to be treated with safety, then the underneath layers will be so sodden as to be totally incombustible.

The chemical treatment of fire-lines with the objective of killing off the natural herbage and precluding its further growth has been tried on an experimental scale with some small success, but at present the cost is prohibitive. Sodium chlorate applied in two or three light doses during the season has been effective in killing a growth of *Calamagrostis epigeios*. Dressings of a third of an ounce per square yard applied once a month during three spring months were more effective than a single dressing of 3½ ounces. The dressing can be spread in crystalline form during wet weather or in aqueous solution at any time.

The layout of fire-belts of species suitable for the arrest of crown fires or to protect conifer plantations from flying sparks from railway engines will generally follow a similar scheme to that of the fire-lines. It is thus usual to form the main fire-belts alongside or on both sides of the principal fire-lines. Like the fire-lines, these belts will be most effective if they are formed to run in somewhat sheltered positions where the oncoming fire is likely to be lulled in its rush by a natural protection from the wind. Unlike fire-lines, however, these belts may prove to be of value as contour strips along the slope of steep hills to check the upward spread of fire. Similarly, a broad hardwood belt on the top of a ridge would serve to check a fire spreading from one range to the next. The selection of species for the formation of fire-belts must depend to some extent upon the factors of locality, but the following requirements are important:

1. The species must themselves be difficult to burn. Poplars, alders, *Robinia*, and elms rank high in this respect.
2. A heavy and dense foliage is required. Beech is best in this respect, but is itself easily killed by a ground fire after it has passed first youth.
3. The species should have a good smothering effect upon ground vegetation. Beech, chestnut, *Robinia*, and alders are thus suitable, but beech humus is liable to be dry and combustible. Japanese larch is a useful conifer.
4. Good coppicing species will enable fire-belts to be kept in uneven aged strips, thus spreading the crown height to the maximum extent. Chestnut, alders, poplars, hazel, and rowan are good. Beech is poor in this respect, though it pollards fairly well.
5. Species which will recover or shoot from the ground after being severely burned will save the expense of replanting after a fire. Beech and Japanese larch are inferior to most species.

Fire-belts, to be of any valuable effect, must be maintained throughout their lifetime in a healthy and strongly crowned condition, and parsimony in their width is a too commonly made mistake. The single or sometimes double lines of hardwood species so commonly seen bordering the main rides and roadsides in forest plantations are merely ludicrous travesties and are utterly valueless. A width of a chain would never be too much, and even this would be barely adequate to maintain the belt under a system of uneven-aged strip regeneration to give the optimum crown distribution and density.

Accessibility to all parts of the forest is an important factor of safety which will be provided by the layout of a well-designed system of rides and pathways varied according to the natural topography. Narrow footpaths in an established plantation create virtually no wastage of ground and are cheaply maintained in a condition suitable for speedy foot or bicycle passage. Apart from the direct needs of rides for proper fire-lines, it should be the rule for every ride throughout the forest to be maintained in such condition that single-file foot or cycle passage at least will be unhampered.

It will seldom be necessary during the very early existence of the forest for permanent look-out stations to be constructed, but their future locations should be very carefully considered beforehand and the opportunity taken to leave unplanted sufficient space around the selected spots. The visibility over the forest area will assuredly become less and less as the crop develops. In flat country the construction of look-out towers may become an early need, but in hilly districts this expense can generally be avoided for a considerable time by a wise pre-selection of observation posts.

FIRE-PROTECTIVE EQUIPMENT.

There should be absolute preparedness for an outbreak of fire, even at the most unlikely season. The forester should take full advantage of all wet weather, during which outside work is impossible, to overhaul and improve his fire-fighting kit. In young plantations the most important items of equipment are fire beaters, of which many different kinds are in common use. A light square-mouthed shovel fitted to a 5-foot ash handle is perhaps the most valuable tool for use in fires occurring in grass, *Molinia*, heather, and other short herbage. Where the soil is of a light sandy texture, shovels are of added value in that they can be used for digging fire-traces in advance of the conflagration and in scattering the soil on to the flames. Shovels, however, are rather expensive and may not be suitable for distribution over the forest in large quantities for the use of the general public, who may be available for assistance. For such purposes a very cheap if little less effective beater is required, which can always be kept in large numbers in dumps available for the immediate use of outside helpers. Fire-brooms or besoms can be constructed from feathery birch twigs bound on to a well-crowned birch or other straight sapling stem. Such implements can be prepared for a very few pence, but their effective 'life' is only a few months before they become brittle and useless. Other cheap beaters may be made by lashing a stout wire ring on to a straight ash handle and covering the circle with three thickness of small-mesh wire netting or with a disk of light gauge sheet metal. Sacks make very efficient fire-beaters, and in young plantations with a grassy herbage are perhaps to be preferred to any other.

Whatever classes of beaters are to be relied on, it is essential to keep really large supplies of them in store at all vantage-points, and furthermore to ensure that they are maintained in really serviceable condition. A large dump of birch besoms which have become completely brittle through long exposure to

the elements is a poor advertisement and a valueless safeguard. Public beater-dumps should be distributed at reasonable intervals alongside all roads through the forest and at other places accessible to the public. At all woodmen's cottages, and other forest houses, further supplies should be stored, together with other tools too valuable to be stored in the dumps open to public use (or misuse). Billhooks or staffhooks are needed where the plantations approach thicket growth or where there is any rank development of coppice, brambles, &c. Ordinary garden spades and mattocks or grubbers will be valuable in case of the need to excavate safety traces in advance of the fire.

Portable fire-sprays, carrying about four gallons of water in a metal or canvas knapsack and fitted with a handpump are useful where there are ample water-supplies, streams, or ponds available, but in general their greatest value is in controlling the burning of fire-lines. Chemical extinguishers have as yet not been found to be practicable for forest purposes. A last item, the proper use of which is as yet known on an experimental scale only, is a gas-mask which would enable fire-fighters to work more safely on the forward side of an advancing fire. A well-wetted soft cloth tied over the nose and mouth is of some service, but it is difficult to devise a really efficient smoke absorbent mask which will be light enough to enable a man to do useful heavy work while wearing it.

PATROLS AND WATCHMEN.

The three equally important duties of the fire patrol are: (1) to prevent the commission of acts likely to result in outbreaks of fire, (2) to spot the occurrence of fires immediately on their outbreak, and (3) to summon assistance with the minimum of delay. It is not the patrol's duty to make any endeavour to extinguish a fire unless he can jump on to it at its very inception or until he is absolutely certain that mass help is on its way. The duties of the fire watchman are similar, excepting that being stationary he will not be in a position to carry out item (1) to much extent. He will normally be stationed at a look-out point and will be supplied with the proper equipment for the immediate transmission of a fire warning to the central depot or place from which help will come. The installation of a post-office telephone system will be the safest, if not always the cheapest, means of transmission of messages from one watch-point to another. Signals by prearranged codes of maroon or siren are other alternatives.

In districts where the fire patrols will have to control the actions of the public it is evident that men of good address will be needed, and in any case the posting of patrols must be limited to employees of real intelligence and thorough knowledge of the forest. Each patrol should be supplied with a written authority from the forest owner, to which may usefully be added a very brief and clear code of his duties and responsibilities. He will, of course, be armed with a fire-beater of some serviceable kind and with a whistle or horn for giving the prearranged alarm signals. Each patrol must cover a defined beat or section of the forest, and he should be acquainted with the boundaries of the neighbouring beats. Under certain circumstances it may be desirable for adjacent

patrols to meet at agreed times and places. In forest fire protection a certain militariness of discipline is essential.

FIRE-FIGHTING ORGANIZATION.

Mere preventive and protective precautions will be inadequate if the organization for fire-fighting is not equally well codified and understood by all members of the forest staff and voluntary helpers who will be called upon in the event of an outbreak. In or near to urban districts a good fire-fighting organization is not difficult to build up, but in remote rural places, where the majority of the important forest areas are situated, this is a task difficult to arrange to ensure sufficient speed and numerical strength. In small villages or townships where the existence of the forest is a not unimportant factor in local politics, a fire warning may be called by means of a simple mouth fire-horn or by a larger siren or maroon. An easily learned code of signals, by sounding a different number of blasts for the various beats of the forest, may be adopted and made known to all forest employees. By such means, as soon as the alarm is sounded every able-bodied inhabitant of the village will know just to which area he should proceed. In larger towns such a simple means would be hardly applicable, but there opportunity will arise for co-operative arrangements with the police, workmen's clubs, groups of factory or other industrial workers, or with regular army or territorial barracks. If the town or village is remote by more than a few hundred yards from the forest, some contemporary arrangement will also be required with an omnibus company or haulage contractor whereby the helpers can be transported without loss of valuable time. (In the case of a haulage contractor it will be important to ascertain beforehand that the Road Fund Licence is in order for the conveyance of passengers.) All such arrangements as may be made with outside helpers should be very carefully laid down in writing, and it is of great importance to ensure that the schemes are revised at least once a year, and that the affected parties are issued with any fresh instructions or kept reminded of the old ones. Voluntary helpers should be aware that they will be suitably recompensed for their labours in the event of fire, and that they will also be reasonably compensated for any loss or damage which they may suffer to their clothing. It may be desirable to limit the age of helpers as cases arise where crowds of mere infants and young girls come to help at fire fighting merely for the sake of receiving payment afterwards and with little intent or capacity of actually serving any useful purpose. While there will be kept a large stock of fire-fighting equipment in the forest, it is nevertheless as well to encourage all voluntary helpers to bring with them a few sacks, a shovel or spade, or some other form of beater.

As soon as the fire has been extinguished the forester will be well advised to summon together all the helpers, voluntary and otherwise, and immediately to take note of payments due and the estimated value of any damage done to clothing, &c. If this is not done it will be difficult at a later date to sift out the genuine from the spurious claims, and it might be impolitic to dispute doubtful cases.

FIRE FIGHTING.

The fire-fighting army must have speed, numerical strength, and adequate equipment. Speed will be governed by a careful layout of roads and rides within the forest and by the system which has been adopted for blazoning the alarm. Numerical strength will be dependent upon the local population, or in remote districts by the plans which have been adopted for summoning distant help. Adequacy of equipment need imply no great expenditure in view of the simplicity of the fire-fighting implements. A few minutes of practical experience in fire fighting in young plantations is more valuable than a wealth of verbal or written instructions, and the forester will be well advised to give practical demonstrations when the opportunity arises to burn over unplanted ground. For herbage fires or fires in young unestablished plantations, beating is the main method of attack, and whether this is done with spades, sacks, besoms, or other forms of beater, the principle is the same. The common mistake, and one which only serves to waste valuable energy in a task which is in any case sufficiently exhausting, is to fight the flames with violent banging of the beater on to the ground. Quite gentle pats have a better smothering effect, and are both less tiring and quicker to perform. With good birch besoms a sweeping action inwards towards the back of the flames is effective. With sacks light swinging blows similarly directed slightly inwards are required.

Excepting in very short grass or heather it is seldom possible to attack the fire from the front, because the wind will be blowing the flames and acrid smoke directly into the workers' faces. An attack from one or both sides is usually the only way to narrow down the frontage into a wedge form and thus to bring it to an easily conquered narrow point. By concentrating the work on one side rather than the other, it may be possible gradually to force the direction of the fire towards a well-kept fire-line or other natural barrier. The freshest and most active men must be kept to the fore where the flames are highest and heat fiercest. The less active or more fatigued men and boys should follow behind, beating out the remnants passed over by the advance party. As the main body follows onwards alongside the fire, so must a rear-guard be left behind to watch the extinguished area and to jump on any smouldering patches which may break out into flame again. If water be available and the water-packs are brought into use, they may be most usefully taken to the front line of attack. A few well-directed squirts with the pump will momentarily quell the fiercest flames to give the front beaters the opportunity to jump in and 'deliver the knock-out blow'.

The forester's place during fire-fighting will be with the men only so long as he is certain that the fire is advancing on a single frontage, and that the efforts of the gang are adequate to beat the conflagration without loss of valuable plantations. If the fire becomes split up or shows signs of getting out of control, then the forester must leave the men and make a hasty survey, possibly from some adjacent hill-crest or other vantage-point. His must be the decision as to any change of tactics, counterfiring, calling out further helpers, or transferring of gangs from one spot to another.

If the fire is approaching at a slow rate or at an oblique angle towards a well-made fire-line, it may be advisable to call almost the whole gang on to this line so that they can attack the fire as it reaches the track, preventing any stray sparks from jumping across to the other side. While waiting for the fire to approach the ride, they may be engaged in cutting any overgrown patches of weed or the edge rows of trees and throwing them far away from the fire-line so that the flames will be small through lack of fuel when they reach the ride. On sandy soils much can be done by scraping up the surface and throwing the material into the flames to smother them. On such a line also, conditions should be at their optimum for counter-firing; a practice which must never be countenanced excepting by the forester himself or some extremely competent man working under his general orders. The principle of the counter-fire is a purposely lit line of fire drawn along in front of the main conflagration and kept under control at its leeward side. As the main fire and the counter-fire approach one another, both automatically die through lack of fuel. A counter-fire may frequently be made along a fairly slender fire-line where it can be adequately controlled, but which would be far too narrow to be a safeguard against a fiercely advancing blaze.

Where fire fighting becomes a long-drawn-out battle the forester must not forget to attend to the welfare of the helpers. Reasonable rest should be allowed to small gangs in rotation before the point of exhaustion is reached. Refreshment, especially of the liquid variety, must be obtained; but nobody should be allowed to drink cold water while remaining at work.

After the fire is extinguished the area must remain under watchful vigilance for a considerable time, because smouldering embers are almost certain to remain and these may be fanned into fresh flame by any slight breeze. Should the amount of smouldering be considerable, and especially if there is much dry peat present, it may be necessary to dig trenches around the worst zones, and watch must be maintained until the soil is wetted by rain. For small amounts of smouldering the use of the waterpack is invaluable.

THE FIRE PLAN.

For any forest of sufficient importance in acreage or in fire risk, the compilation of a written fire plan setting out the details of the protective scheme serves a twofold purpose. Firstly, it contains instructions of a prescriptive nature for works to be carried out at defined times by the forest staff. Secondly, and equally important, its periodical scrutiny, perhaps in the light of any fires which may have occurred, will indicate the need for revisions, extensions, or simplifications.

The fire plan needs to be simple in its conception but definite in its prescription. Supported by a map it will show the division of the forest into any necessary units for control or patrol purposes, location of all dumps of fire equipment, areas of special fire risk such as railway lines, the position and number of look-out posts, telephones, woodmen's houses, and main accesses. Incorporated in the plan must be the full details of working arrangements in

co-operation with outside helpers, together with any code of signalling to be adopted for calling out helpers. The duties and general policy to be followed by fire patrols should be defined, but the local forester must be given absolute authority to vary the numbers and locations of the patrols according to daily local needs. The fire plan should be scrutinized in detail at least once a year, and a programme of capital or maintenance works drawn up for the coming twelve months. At the same time the opportunity should be taken to incorporate any amendments which local experience has shown to be desirable.

SUMMARY.

Fire protection in young plantations is a very different matter from the protection of old-standing woodlands, but in the formation of plantations the future fire-protective needs of the grown forest must be kept in mind.

The origin of forest fires is discussed, followed by a description of the types of fires with especial reference to surface fires in different classes of vegetation.

The prevention of fires by discouraging dangerous actions on the part of the public is discussed.

The layout of young plantations to render them as fire-safe as possible, while also planning for the future established forest is considered and the various types of fire-lines and fire-belts are described.

The equipment required for combating plantation fires is considered and described. The duties of fire patrols and watchmen are mentioned.

The arrangements to be made for a fire-fighting organization and the enlistment of a large enough body of helpers are discussed.

A brief description of the principles of fire fighting in young plantations is given.

The compilation of a codified fire plan to define the fire-protective policy organization, and programme is recommended.

THE AFFORESTATION OF DIFFICULT PEAT AND UPLAND-HEATH SOILS

AN EXTRACT FROM ANNUAL PROGRESS REPORT ON THE RESEARCH WORK OF THE FORESTRY COMMISSION FOR YEAR 1937

BY W. H. GUILLEBAUD

(Chief Research Officer, Forestry Commission)

THE following extract, published by permission of the Forestry Commissioners, summarizes the results of a series of plantation experiments established during the past 15 years, and concerned with various aspects of the treatment of certain 'difficult' types of land.

The extract falls into three sections:

I. Preparation of ground and planting methods on Peat soils.
II. Preparation of ground and planting methods on Upland-*Calluna* soils.
III. The use of pine-spruce mixtures on Upland-*Calluna* soils.

Appended to the extract is a series of brief notes outlining the conditions prevailing in the several forests mentioned. In some cases it has been possible to give references to descriptive papers from which fuller information can be obtained.

Section I. PREPARATION OF GROUND, AND PLANTING METHODS, ON PEAT SOILS.

(*a*) *Direct Planting into the Natural Surface.* In the early days of the experimental work at Inchnacardoch[1] and elsewhere in the west of Scotland many experiments were made with different methods of direct planting. The more elaborate of these were based on the belief that the roots might penetrate broken-up peat more readily than peat in its natural conditions, hence various forms of pitting, mattock trenching, &c. These all failed to produce satisfactory growth on the fibrous peat of the Scottish Highlands. Vertical notching and pitting resulted in the death of the majority of the spruces, while methods of shallow planting designed to place the roots near the surface also failed except in one experiment at Glenrigh, where the natural drainage was good.

It should be observed that results with the direct notching of spruces on the amorphous types of *Molinia* peat of the Cheviots and Pennines are much less unfavourable to this method. Losses are usually higher than by turf planting, and growth appreciably slower, but provided a reasonable amount

[1] Notes on the factors of locality of the different forests in which the experiments are located are given in an appendix.

of drainage is done it is possible to secure satisfactory plantations by this means; Moorburnhead Plantation is a case in point.

(*b*) *Standard Methods of Turf Planting.* These have proved a great advance over direct planting on all types of peat, both as regards reduction of losses on planting and also, as a rule, as regards rate of growth. In some of the experiments, however, turf planting resulted in heavy losses during the first year. This occurred almost exclusively on the fibrous types of peat when planting was carried out before the turfs had time to settle properly and the weather following planting was very dry.

As regards the effect of turf planting upon rate of growth, on the poorer types of pseudo-fibrous peat, e.g. *Calluna-Scirpus*, growth after the first few years may be little better than in the case of direct notching. In both cases the result is a complete state of check, but the turfed plants, so far, remain for the most part alive, while those planted direct gradually die. On this type of land the effect of manuring turfed plants with basic slag is greater than any improvement that can be effected by method of planting alone.

(*c*) *Experiments on Methods of Turf Planting.* A number of experiments carried out on the poorer peat types at Inchnacardoch and Achnashellach may be mentioned here very briefly. Nothing was gained by planting on turfs taken from the lower levels of a deep peat bog as compared with surface peat. Draining and laying out the turfs 3 years in advance of planting was not helpful at Inchnacardoch. No advantage resulted from putting a planted turf on top of another turf in which a cavity had been formed, the object being to improve aeration. Experiments on the lifting of badly checked spruce on fibrous peat were generally unsuccessful, losses were very high and relatively few of the plants recovered. The most intensive treatment, consisting of lifting the checked plants, applying basic slag, and putting in new drains, has been a success, but it is questionable if it would not be better to replant *de novo* using standard turf planting.

The most interesting of the special methods of turf planting employed is the system of group planting tried at Inchnacardoch and Glenrigh, where three turfs are placed round a central planted turf. Such concentration of the turfs combined with the more intensive drainage favourably alters the vegetation and promotes the growth of the trees. This result points the way to ploughing as the probable solution of the problem of the afforestation of the poorer peat soils (fibrous and pseudo-fibrous types).

(*d*) *Dug-over Peat.* Owing to lack of the necessary implements it has been impossible to experiment with ploughed-up peat of the type found in the Highlands. Imitation ploughing (turning over the peat by hand) has been carried out at Borgie, where 1½ acres of deep *Calluna-Scirpus* peat were dealt with in this manner. After 7 growing seasons the average heights of the trees were as follows:

Sitka spruce	4 ft. 10 in.
Pinus contorta	4 ft. 10 in.
Scots pine	3 ft. 2 in.

All the plants received the usual dose of basic slag. This result on a definitely bad type of peat is quite encouraging although, as there was no ordinary turf planting carried out alongside as a control, it is difficult to say exactly what part the cultivation has played. The nearest turf planting is about a mile away on the opposite side of the valley, and though the ground is not dissimilar, it is unsafe to make a comparison.

Hand digging has also been carried out on a number of *Scirpus-Calluna* knolls carrying a thin skin of fibrous peat. There are experiments at Nevis, Bennan, Borgie, Inchnacardoch, Blackcraig, and Glenrigh Forests, all of which were carried out in P. 35 and P. 36.[1] The results have been generally unfavourable as compared with direct planting or planting on replaced turfs, the feature of the dug-over areas being the very heavy death-rate which occurred in the first season after planting. These knolls present a special problem owing to the tendency of the disturbed soil to dry out during a summer drought.

Conclusions. The experimental work provides definite evidence justifying the adoption of the standard method of turf planting on peat soils. The method is equally applicable whether the species is Sitka spruce, Japanese larch, Scots pine, or *Pinus contorta*. On the poorer types of peat the success of the turf group and imitation ploughing methods (in conjunction with basic slag) in improving the natural vegetation points to intensive cultivation as a possible solution of the problem of these peats. Half the battle will be won if grasses can be brought in to replace the heather and *Scirpus*, and the surest way of effecting such a change is to turn over the surface peat as completely as possible. The addition of basic slag will probably be necessary in most cases.

Section II. PREPARATION OF GROUND, AND PLANTING METHODS, ON UPLAND-*CALLUNA* SOILS.

The most important series of experiments in Scotland is in the large experimental area of Teindland. On this compacted and naturally ill-drained, impoverished soil the effects of cultivation are usually very well marked. A P. 28 experiment contrasts the growth of three species planted (A) by direct notching into the undisturbed soil and (B) on mounds, the latter involving a considerable amount of local soil cultivation as well as locally improved drainage. The results are as follows (after 10 growing seasons):

Species.		*A. Direct notch.*		*B. Mound planting.*	
		Unmanured.	*Manured.*	*Unmanured.*	*Manured.*
Japanese larch	mean height, in inches	23	40	36	67
	per cent. of losses	43	31	21	7
Scots pine	mean height, in inches	22	35	32	43
	per cent. of losses	26	7	23	15
Pinus contorta	mean height, in inches	16	36	27	52
	per cent. of losses	33	17	25	16

Growth of all species planted by direct notching without basic slag has been painfully slow. An average total height of less than 2 feet in 10 years is not

[1] P. 36 is Planting Year 1936 = autumn 1935 to spring 1936.

much of a result. Mound planting clearly improves matters, though it is worth noting that the heights of the unmanured mounded plants are less than those notched in direct, but with manure. In this experiment the combination of mound planting and manuring with basic slag has given much the best results. That drainage is an important factor on this Teindland area is well illustrated by a P. 26 experiment with Scots pine. Whereas the plants on the undrained ground averaged only 15 inches in height after 12 years, those planted between drains averaged 27 inches (range 17 to 35 inches), while those put in along the drain-sides averaged 40 inches (range 27 to 55 inches).

In P. 27 and P. 28 a fairly elaborate ploughing experiment was carried out in the same experimental area at Teindland. There were three methods of ploughing, i.e. full ploughing, double-furrow ploughing, and double-furrow ploughing with a subsoiler, following the plough. The plough was specially constructed for the work and was drawn by three horses. Considering the nature of the soil and the numerous boulders it did very good work, but its performance was certainly much inferior to that of the modern tractor-drawn ploughs. Even where the subsoiler was used the iron pan was seldom reached or broken.

A variety of species and mixtures was tried, including mixtures of Sitka spruce and Norway spruce with *Pinus contorta* and mountain pine; these will be referred to later in this report. For the present purpose it will be sufficient to give the data regarding the growth of Scots pine and *Pinus contorta*, both species which, where planted direct, without cultivation, have made little progress. Ploughing was carried out in P. 27, and half the area was ploughed in that year and the other half in P. 28.

The average heights in inches of the unslagged and slagged plants of the two species, at the end of P. 37, are as follows:

	Scots pine.		*Pinus contorta.*	
	P. 27.	*P. 28.*	*P. 27.*	*P. 28.*
	in.	in.	in.	in.
Full ploughing — no slag	43	50	34	60
Full ploughing — slagged	57	51	38	77
Two-furrow ploughing — no slag	50	32	42	52
Two-furrow ploughing — slagged	58	46	41	75
Two-furrow ploughing subsoiled — no slag	54	27	38	69
Two-furrow ploughing subsoiled — slagged	68	53	47	83
Mean — no slag	49	36	38	60
Mean — slagged	61	50	42	78

The data showed no consistent trend as regards the effect of the three methods of cultivation and it was quite apparent on the ground that this is due to local soil variations. The effect of slag has also been rather variable. The stimulus has been greatest on the poorest sites and so has had a levelling-up effect; this is particularly noticeable in the case of Scots pine of P. 28 ridge ploughing. The *Pinus contorta* used in the P. 27 planting were apparently a poor lot, the P. 28 plants giving a much better result.

If we compare the growth of the P. 28 Scots pine with that of the P. 28 *Pinus contorta* the difference is not very great, and it is possible that in 10 years' time there will be little to choose between the two species as regards height growth. The experiment did not include a direct planted control, but there is sufficient evidence on the area as a whole to leave no doubt as to the beneficial effect of the ploughing.

In P. 29 a large-scale ploughing experiment was carried out, covering an area of about 10 acres within the reserved Compartment at Teindland. Mound planting (incidentally a very expensive method of soil preparation) was contrasted with shallow cultivation by horse plough, there being two methods: three-furrow ploughing planted at normal spacing, and complete ploughing planted in closely spaced groups. The species used was *Pinus contorta*, half the plants were put in in P. 29 and the remainder in P. 30.

The results are summarized in the following tables:

	P. 29 planting. Average height after 9 growing seasons.		*P. 30 planting. Average height after 8 growing seasons.*	
	Unmanured.	*Manured with basic slag.*	*Unmanured.*	*Manured with basic slag.*
	in.	in.	in.	in.
Planting on mounds . .	35±5·3	55±7·9	34±6·2	51±5·4
Three-furrow ploughing .	32±2·4	72±4·8	35±2·4	61±4·0
Complete ploughing (planted in groups)	34±8·3	80±2·9	36±6·9	67±9·1

Without manure, growth has been relatively slow and there is nothing to choose between the three methods of soil preparation. With manure the trees can reasonably be regarded as established, and there is a distinct indication that the more intensive cultivation provided by ploughing has been beneficial. The high standard errors reflect the very variable growth of the trees; probably in a few years' time when canopy has formed the plantation will even up and differences between the initial treatments may slow up more clearly.

The effect of cultivation comes out perhaps most definitely in Experiment 36, P. 29, at Teindland. Here Scots pine and *Pinus contorta* were planted in groups some of which were dug over, representing complete cultivation, while in others the plants were put in on the natural unbroken surface. Half of the groups were manured with basic slag (2 ounces per plant), the other half being left as unmanured controls.

		Average heights of plants in inches after 9 growing seasons.	
		Uncultivated.	*Cultivated.*
Scots pine	no slag . .	13	28
	slagged . .	16	53
Pinus contorta	no slag . .	20	26
	slagged . .	29	63

The outstanding results are from the slagged and cultivated groups of both species as compared with the uncultivated, unmanured controls.

It is clear that cultivation alone is insufficient to produce satisfactory results on this very poor land.

One further experiment is of interest as bearing on the problem of the cultivation of these poor wet *Calluna* heaths. The experiment was based on the experience of the Danish Heath-reclamation Society which supports the use of intensive cultivation before planting the forest trees. The cultivation extends over a period of years during which at least two agricultural crops are harvested. In 1933 plots were laid down at Teindland in which two treatments were tested: (A) the surface was broken up by a single ploughing, and (B) the soil was intensively cultivated by twice ploughing and twice cultivating. The experiment differed from the Danish practice in that no agricultural crops were taken (this was done in a later small-scale experiment).

The results, at the end of 5 growing seasons, are as follows:

	Single ploughing.		*Intensive cultivation.*	
	Losses per cent.	*Average height.*	*Losses per cent.*	*Average height.*
	A. *Without slag.*			
		in.		in.
Sitka spruce	30	9	11	8
Japanese larch . . .	71	10	48	6
Birch	45	12	36	7
Oregon alder . . .	100	—	100	—
	B. *With slag.*			
		in.		in.
Sitka spruce	8	23	0	22
Japanese larch . . .	40	25	2	36
Birch	27	26	4	16
Oregon alder . . .	6	75	7	117

The data are remarkable from several points of view. Intensive cultivation without any manuring has not helped at all except to reduce to some extent the proportion of failures in the first three species. Oregon alder died out completely in both forms of soil cultivation. As regards growth, all species are in check, and it is interesting to find birch making such a poor showing on the intensively cultivated ground.

Where basic slag was applied both Sitka spruce and Japanese larch are showing signs of growth, particularly the larch on the intensively worked sections. Birch is only relatively better than on the unmanured plots and clearly finds the conditions unsuitable. Oregon alder has done by far the best of the species tried: the slag has converted a complete failure into a 95 per cent. take, and the plants have attained the very considerable height of from 6 to nearly 10 feet in 5 years.

The other poor *Calluna* area in which experiments on soil cultivation have

been carried out over a period of years is in Yorkshire, at Allerston and Harwooddale. At Allerston the effects of cultivation are well marked, although, as the soil conditions are less unfavourable than at Teindland, growth of pines on the uncultivated ground are relatively better.

Experiment 6, P. 28, shows the effect of shallow ploughing compared with planting into a screefed patch of uncultivated soil. No slag was applied.

Growth after 10 years

	Screef-planting.		*Three-furrow ploughing.*		*Full ploughing.*	
	Average height.	*Average shoot.*	*Average height.*	*Average shoot.*	*Average height.*	*Average shoot.*
	in.	in.	in.	in.	in.	in.
Scots pine . .	41	8·5	47	10·6	56	12·8
Corsican pine .	32	7·5	46	10·6	51	11·4
Sitka spruce . .	14	0·9	29	4·1	29	4·0
Japanese larch .	16	2·7	34	8·2	59	12·8

The Scots pine in the screef-planted controls without slag are nearly as tall as the same species on fully ploughed and slagged ground at Teindland. Ploughing has, however, quite appreciably increased the rate of growth. The effect of cultivation is more marked on the Corsican pine, full ploughing nearly doubling the height of the plants. Ploughing has brought the Sitka spruce out of check, but the most striking difference appears in the Japanese larch, and it will be noted that on the fully ploughed ground the plants average about 5 feet in height, as compared with only 1 foot 4 inches in the screefed patches.

From P. 31 onwards at Allerston the ground was broken up with a heavy plough drawn by caterpillar tractor, giving much deeper cultivation than in the earlier experiments. A direct comparison of the two methods of ploughing is not possible owing to soil variations, the shallow ploughing being on the poorest ground. The growth of pines on the deeply ploughed land is very satisfactory, and there is a distinct tendency for growth to improve with the intensity of cultivation, i.e. the plants are better on the fully ploughed ground than where the ground has been ridged up by double-furrow ploughing at 4½ feet apart. On the other hand, at Wareham, where the introduction of ploughing has led to a remarkable improvement in the early growth of the pines, ridge ploughing generally gives better results than full ploughing.

Conclusions. As on all other types of soils it is dangerous to generalize too broadly as to the effect of cultivation on the poor *Calluna* heaths. Results vary with the locality and species, but at least it is true to say that cultivation by digging or ploughing effects a general improvement in the conditions for tree growth. The hardy, unexacting pines benefit as a rule less obviously than such species as Sitka spruce, Japanese larch, birch, or alder. On the poorest type of land, e.g. the top of Teindland, cultivation alone is insufficient to produce satisfactory growth even of the pines; basic slag must be added to give the plants a proper start. The more exacting species, Sitka spruce,

Japanese larch, &c., cannot be grown at all without cultivation and slag. Their ultimate fate is still in the balance, because there is always a risk of second check before canopy is formed.

On the better *Calluna* soils, such as Allerston, the pines respond well to cultivation but, given good plants and good planting, as well as a favourable planting season, may ultimately make a satisfactory plantation without such treatment. Growth is, however, always more irregular than on ploughed ground and usually failures are higher. It is with the more exacting species that cultivation becomes all-important. If, as appears very probable, the production of many of the *Calluna* areas can be increased by including a proportion of spruce with the pine, ploughing is an essential preliminary for the successful establishment of the mixture.

Section III. THE USE OF PINE-SPRUCE MIXTURES ON UPLAND-*CALLUNA* SOILS.

A survey has been made of those experiments in which mixtures of pines and spruces occur. Many of these are too young for the pine to have any influence, and in some cases the pine have failed to develop owing to damage by blackgame or to unsuitable planting methods. Where the pine have grown satisfactorily and have reached a height of not less than 3–4 feet, there is evidence of a definite improvement in the rate of growth of the spruce. Data from experiments at Teindland, Allerston, Inchnacardoch, and Kielder forests are summarized below.

(*a*) *Teindland.* Experiment 16, P. 27, and 23, P. 28, on shallow-ploughed, poor, Upland-*Calluna* ground. The plots summarized in the table all received an application of basic slag, and the data represent in each case the mean of 6 plots.

Average heights in inches of plants after 12 and 11 growing seasons respectively:

	Norway spruce mixed with			*P. contorta in N.S. plots.*	*P. montana in N.S. plots.*
	(*a*) *P. contorta.*	(*b*) *P. montana.*	*Pure.*		
P. 27	19	21	17	42	42
P. 28	23	28	18	75	38
	Sitka spruce mixed with			*P. contorta in S.S. plots.*	*P. montana in S.S. plots.*
	(*a*) *P. contorta*	(*b*) *P. montana.*	*Pure.*		
P. 27	38	35	29	41	41
P. 28	45	39	35	86	38

There are several points for mention in the above table. In the first place the spruces have benefited in every case by admixture with pine, but whereas Norway spruce appears to have done relatively better in mixture with mountain pine than with *Pinus contorta*, the reverse is the case with Sitka spruce. Secondly, three out of the four species (mountain pine is the only exception) have grown better in the P. 28 experiment; the ground was all ploughed in

P. 27 and possibly the delay of a year before planting has been beneficial; the difference is most marked in the case of *Pinus contorta*. Thirdly, Sitka spruce has grown nearly twice as fast as Norway spruce on this poor ground.

(*b*) *Allerston*. Experiment 6, P. 28, on shallow-ploughed, poor, Upland-*Calluna* soil, not slagged. The data represent in each case the mean of 18 plots, after 10 growing seasons.

	Sitka spruce.				*Scots pine in Sitka spruce plots.*
	Pure.		*Mixed with Scots pine.*		
	Average height.	*Average length shoot.*	*Average height.*	*Average length shoot.*	*Average height.*
	in.	in.	in.	in.	in.
No slag . . .	21	1·4	29	4·1	51
Slagged . . .	32	3·4	39	6·6	63

The effect of the pine mixture is less apparent in the mean heights of the Sitka spruce than in the current leading shoots. The difference in colour of the needles is very apparent on the ground, and it is probable that the spruce in the spruce-pine mixtures will now grow rapidly ahead of those in the pure plots.

(*c*) *Inchnacardoch*. Experiment 16, P. 27. This experiment has already been written up by Mr. J. A. B. Macdonald in the *Scottish Forestry Journal*, published in October 1936. The experiment started in P. 23 with a series of season-of-planting plots with Sitka spruce planted by direct notching. The ground was rather variable and three distinct soil types are now recognized. In P. 27 alternate plots were inter-planted with Scots pine, and in 1935 an assessment was made of the relative growth of the spruce in the pure and the mixed plots on each of the three vegetation types. The spruce were then 13 years old and the pine 9 years old, from the date of planting.

	Sitka spruce		
Vegetation type.	*Mixed with Scots pine.*	*Pure.*	*Scots pine in S.S. plots.*
Dry and exposed *Calluna/Erica cinerea* slopes	Height 2·9 ft.	1·7 ft.	9·3 ft.
	Shoot 7 in.	2 in.	20 in.
Sparse bracken, grass, and *Calluna* . .	Height 8·8 ft.	4·2 ft.	13 ft.
	Shoot 20 in.	5 in.	25 in.
Strong dense bracken, grass, and *Calluna* .	Height 13·3 ft.	8·9 ft.	14·2 ft.
	Shoot 26 in.	19 in.	24 in.

In each type the pine admixture has improved the growth of the spruce in a very marked degree. This is good pine ground and the pines started away without any check. The spruce in the mixed plot on the poorest ground put

on an average shoot of 7 inches in 1935, which compares with only 2 inches in the control. It is also remarkable that the pine admixture should have apparently had such a great effect on the development of the Sitka spruce on the good, dense bracken type.

(*d*) *Kielder* (*Smales*). Experiment 6, P. 27, planted on turfs on *Calluna-Molinia-Eriophorum* peat. Assessed in 1937, i.e. after 11 growing seasons. The data are given in inches and represent the means of two plots.

	Sitka spruce.		
	Mixed with Scots pine.	*Pure.*	*Scots pine in S.S. plots.*
	in.	in.	in.
Average height . . .	66	54	51
Average leading shoot . .	8·5	6·4	9

In this example also there is an indication of improved growth of the spruce in the mixed plots.

(*e*) *Forest of Deer.* The following note was prepared by Mr. J. A. B. Macdonald on an interesting case of a pine-spruce mixture in the Forest of Deer. The Sitka spruce were introduced four years after the pine.

'A visit was made on 18th April, 1938, to a ridge top in Forest of Deer where the Chairman had observed Sitka spruce coming on well among Scots pine. The area is in Compartment 10, P. 27, at a height of 410 feet; but as there is little high ground intervening between this and the sea—10 miles away—exposure is severe. The underlying rock is quartzite, and there is a 10 in. covering of black, humose material which in the slightest hollows is definitely peaty in texture. The area was old woodland containing Norway spruce, Scots pine, and some European larch. Apparently the Scots pine had started reasonably well, but before they had grown much above the level of the herbage many of them were very badly blasted and quite a number died. Sitka spruce were introduced on turfs in 1931 to beat up gaps.

'A measurement made this year gave the following heights in inches for Sitka spruce and Scots pine:

(1) *On a Calluna/Nardus type:*

S.S. 19, 11F, 17F, 13F, 12F, 13, 20, 7F, 22, 19. Average: 14 inches.
S.P. 15, 14, 21, 19, 16, 20, 16, 16, 15, 20. Average: 17·2 inches.

The Scots pine were very badly blasted and in most cases the leading shoots had been killed. The Sitka spruce marked "F" showed signs of frost damage.

(2) *On a Calluna/Aira flexuosa/mosses association, the heights in feet were:*

S.S. 4½, 5½, 4½, 5½, 2F, 4, 3½, 5½, 4½, 3½. Average: 4·3 feet.
S.P. 3, 1½, 2, 1½, 2, 2, 2½, 2, 2, 1½. Average: 2 feet.

The Scots pine were badly browned on the N/NW side, but were not blasted to anything like the same extent as on the *Calluna/Nardus* type of ground.

(3) *On an Aira flexuosa/Calluna/Galium saxatile site*, the Scots pine had done much better, heights in feet being:

S.S. 3½, 1½, 1½, 3, 4, 5, 4, 6½, 4, 1½. Average: 3·5 feet.
S.P. 7, 5, 6, 5, 3, 3½, 4½, 3, 3½, 4½. Average: 4·5 feet.

Each Scots pine tree in this group had an entire leading shoot, and none of the Sitka spruce had been blasted.

'It appears, therefore, that only in the *Calluna/Nardus* types have the Scots pine failed. It was found that this vegetation type occurred in very slightly concave parts of the ridge, where undoubtedly drainage was impeded. A search showed that *Sphagnum* species occurred in these shallow depressions, also *Juncus squarrosus*. A distinct pan was found at 10″ below the surface in one such hollow and the underlying subsoil was definitely gleyed. It is interesting to find that both blasting by wind and frosting occurred together in these partially waterlogged patches and not at all on the slope, or where the surface was convex as in samples (2) or (3).'

Conclusions. The evidence from the above experiments and observations appears to justify the use of mixtures of pine and Sitka spruce on those wet *Calluna* types where experience has shown that spruce is liable to check for a number of years before getting away. The plot in the Forest of Deer also shows that use can be made of a slow-growing pine crop to bring in Sitka spruce and that these will benefit from the shelter provided by the pine.

The exact part played by the pine in the mixed plots is not fully understood. The pine presumably have a sheltering effect in the earlier stages. Later on the (usually) faster-growing pine will bring about earlier suppression of the heather and other vegetation, which must help the root development of the spruce. Ultimately, especially on Upland-*Calluna* soils in which the pan has been disturbed by ploughing, the deeper-rooting pine will certainly tend to a more effective penetration of the soil besides contributing to the stability of the crop in the event of windstorms.

APPENDIX: DESCRIPTIVE NOTES ON THE FORESTS.

Forests referred to in Section I.

Inchnacardoch Forest. This forest is situated near the town of Fort Augustus on the Caledonian Canal and is one of the principal centres of the experimental work on the planting of peat in the centre and west of Scotland. The rainfall is about 45 inches per annum. The rocks belong to the Highland metamorphic series which here are highly quartzose. The experiments deal with two distinct topographical conditions, namely, with a basin peat bog known locally as the Lon Mor and with the middle slopes of the main ridge on the west side of the Great Glen. In the basin peat bog the peat is deep, relatively uniform in character, and of what Dr. G. K. Fraser terms the Scirpus High Moor type.[1] The vegetation consists of dwarf *Calluna*, *Scirpus*, *Molinia*, *Erica Tetralix*, *Myrica gale*, &c., with a dense carpet of *Sphagnum* moss.

On the sloping ground the peat is seldom over 12 inches in depth and usually shallower, the composition is very variable, *Calluna-Scirpus* peat on the ridges alternating with a semi-flush type of peat in the intervening depressions and gullies. The tough 'pseudo-fibrous' *Scirpus* peat is very difficult to drain and is one of the most intractable types of land we have for afforestation.

Glen Righ Forest is situated near Onich to the south of Fort William, and

[1] *Studies of Scottish Moorlands*: Forestry Commission Bulletin No. 15.

on the east side of the Caledonian Canal. Conditions here are generally similar to those on the sloping ground at Inchnacardoch except that the rainfall is considerably higher, averaging about 80 inches. The experimental plots are almost all on bad *Scirpus* peat.

Achnashellach Forest lies in Glen Carron, Ross-shire. With an annual rainfall of about 100 inches the area is even wetter than Glen Righ. Although the slopes are for the most part steep, *Calluna-Scirpus* peat has developed on most of the higher ground and especially on the crests and sides of the small longitudinal ridges which run up and down the slopes.

Borgie Forest is situated in the north of Sutherlandshire, near Tongue, and has a rainfall of about 40 inches per annum. The rocks are quartzose and a poor type of *Calluna-Scirpus* peat has formed on all except the steepest slopes above the valley bottom. The remaining forests mentioned in connexion with the experiment on peat include *Nevis*, *Bennan*, and *Blackcraig*. Nevis is on the slopes of Ben Nevis in Inverness-shire, Bennan on the Dee in Kirkcudbrightshire, and Blackcraig near Blairgowrie in Perthshire. The only feature common to these forests is the presence of many small morainic knolls composed of tightly packed morainic deposits and carrying a vegetation composed in the main of *Scirpus* and *Calluna*. The peat is shallow but very tough, and these knolls present a difficult problem in afforestation.

Forests referred to in Section II.

Teindland Forest[1] is situated about seven miles from Elgin in Morayshire and occupies the north-east slopes of a hill known as Finlay's Seat, which rises to nearly 900 feet above sea-level. The mean annual rainfall is about 30 inches. The soil is a very strong boulder till derived from Old Red Sandstone conglomerate. Near the top of the forest, where the experimental area is situated, the soil is heavily leached and there is a well-marked iron pan at a depth varying between 8 and 16 inches from the surface. The vegetation consists of short scrubby *Calluna*, *Erica Tetralix*, *Carex panicea*, *Scirpus*, *Cladonia*, &c. From 2 to 4 inches of peaty matter overlie the mineral soil.

Allerston Forest[2] comprises a number of large blocks of partly moorland and partly dale-land in the North Riding of Yorkshire, west of Scarborough. The rainfall is about 35 inches per annum. The rocks consist of siliceous sandstones of the Middle Oolite and give rise to a rather fine-textured sandy soil containing from 30 to 40 per cent. of silt and clay particles. The experimental areas are situated on the moorland sections of the forest. Here the soil is leached and a thin iron pan usually occurs at about 8 inches below the surface. A layer of from 2 to 3 inches of *Calluna* raw humus rests on the mineral soil. The vegetation consists of *Calluna* as the dominant species, with occasional plants of *Carex binervis*, *Juncus squarrosus*, &c. Where wetter conditions prevail *Erica Tetralix* becomes abundant and *Scirpus* also occurs.

[1] For a more detailed description see article by A. Muir on 'The Soils of the Teindland State Forests', *Forestry*, vol. viii, no. 1.

[2] See 'A Study of Some Yorkshire Moorland Soils', by G. V. Jacks, in *Forestry*, vol. vi, no. 1.

Wareham Forest occupies a stretch of low-lying heath on the Bagshot Sands to north of Wareham in Dorset. The rainfall is about 35 inches per annum. The soil is extremely variable in character but is typically a fairly coarse and heavily leached sand. Patches of gravel also occur, and in places the sand rests without visible change in colour on a whitish clay. The vegetation is relatively poor in species, consisting chiefly of *Calluna* with *Erica Tetralix*, *Agrostis setacea*, and *Molinia caerulea*. Bracken comes in on the drier slopes. Apart from the steeper ridges the natural drainage is poor and conditions are not easy for the establishment of trees.[1]

Forests referred to in Section III.

Inchnacardoch Forest. The experiment described is situated near the foot of the main slope and is on a dry heath or grass/heath site very different from the peaty moorland conditions which prevail higher up the hill.

Kielder Forest is situated in Northumberland and stretches from near Bellingham on the North Tyne to the Scottish Border. The rainfall is in the neighbourhood of 40 inches per annum. This is undulating country with long gentle slopes rising gradually up to the main ridge of the Cheviots. The underlying rock is Carboniferous sandstone, but most of the area is overlain by glacial drift and till. The greater part of the afforestable land is covered with grass associations in which *Molinia caerulea* is the dominant species, but there are also considerable areas carrying *Calluna* in association with cotton grass, *Molinia*, and *Scirpus*, and it is on these types that most of the experiments are situated. The depth of peat is usually less than 12 inches.

Forest of Deer. This forest is situated in the district known as Buchan, in the north-east of Scotland. The average rainfall is 25 inches per annum, and the district is particularly subject to late frosts. The geology, soil, and vegetation types vary widely within the forest, but those for the sites referred to are given in the note already quoted.

[1] See articles by Dr. M. C. Rayner in *Forestry*, vol. viii, no. 2; vol. x, no. 1.

ECOLOGICAL ASPECTS OF AFFORESTATION IN THE HILL COUNTRY—CRITERIA IN THE CHOICE OF SPECIES[1]

BY H. M. STEVEN

INTRODUCTION.

IN this paper, the criteria which have to be taken into account in the choice of species for afforestation in the hill country are briefly considered. Thereafter, the plantations so formed are viewed from the ecological aspect, and consideration is given to their deficiencies from that point of view. Finally, suggestions are made as to how they can be brought more into accord with the ecological ideal.

CRITERIA IN THE CHOICE OF SPECIES.

The selection of species for afforestation where there is limited evidence of tree-growth, which is typical of our hill country, is a matter of the greatest difficulty, as all who have to do it know. It is, however, a task of first importance for the future success of the afforestation work in this country.

The criteria which may have to be considered can be grouped conveniently into four categories:

1. Aesthetic considerations.
2. Economic considerations.
3. Factors inherent in the species.
4. Factors inherent in the site.

Sport is not included because woodlands in the hill country are much less important from this point of view than in the lowlands.

Aesthetic Considerations.

This subject is too controversial for adequate discussion on this occasion. The school who hold that only indigenous species should be used need not be considered seriously, because if this doctrine was applied to crop plants in general the results would be too far-reaching. In considering woodlands from the aesthetic point of view, one should, I think, differentiate between the distant and the near view. In the former, the general mass effect is of greatest importance, and there is evidence, particularly in Scotland, that even pure conifers are not to be condemned on this ground. The near view, however, calls for variety both in form and colour. It is suggested, therefore, that aesthetic considerations should only have principal weight at strategic points.

Economic Considerations.

The first question is whether one should aim at quantity or quality. Here there is a conflict in national interest. On the one hand, quantity cannot be

[1] This paper was delivered at the British Association Meeting at Cambridge, August 1938.

ignored if defence considerations are to remain important, while, on the other, the quality of much of our home-grown timber puts it into the lower grades, and an improvement is called for. When used in the raw state it is the macroscopic factors of quality such as ring-width, knottiness, &c., which are important. Knottiness and other defects can be modified by treatment, but if the maximum quantity is to be aimed at, then fast-growing species such as Douglas fir and Sitka spruce must be fully exploited on suitable sites. All the present evidence, however, points to the probability that timber will be used to a decreasing extent in a raw state. For pulp, fibre length is the most important point, while in plywood part of the timber used need not be of good quality. Of considerable interest in this connexion are the recent developments in Germany; in certain new processes species and quality do not appear to be important. Forssmann wood, for example, is built up of many (fifteen) thin slices of wood, 0·1 mm. thick, cemented together by still thinner layers, 0·03 mm., of bakelite. It is stated to be based on the fact that the tensile strength of the actual wood-cells is very high, and it is the cell connexions which are the weak links. In this process the bakelite forms the connexions, and a very strong product results which is stated to be independent of species and quality. Similarly, the production of *zellwolle* is independent of fibre length, although the resulting fabric is different from rayon. It is unlikely that, in the near future at least, all our timber will be boiled up in vats or cut into paper-like sheets, but it is almost certain that there will be an increasing demand for timber for which the principal requirement will be bulk of wood substance rather than the present-day criteria of quality.

The second important economic consideration is the cost of producing different species. This is also essentially a question of rate of growth, although costs of formation, maintenance, &c., come into it. The calculations made by Hiley showed that the cost of production per cubic foot for a tree of given size varied widely for different species. The costs for Sitka spruce and Douglas fir are low, then comes Norway spruce, then European larch and Corsican pine, while that for Scots pine is about five times that for Sitka spruce, and oak is much higher than any conifer. It is this consideration, of course, which leads us to prefer other conifers to Scots pine, when there is a choice; explains the popularity of larch; and is one reason for the extended use of Sitka spruce; because, except that larch consistently fetches a higher price, there is not much difference between the prices of other conifers.

To sum up, economic considerations indicate that we should make full use of the capacity for rapid growth both in species and sites. Where conditions are not favourable for this, for example on a large area which will only give slow-growing but good Scots pine, we should concentrate specially on quality production.

Factors inherent in the Species.

There are numerous specific characteristics which have a bearing on the selection of species.

Moisture Requirement. We have little precise knowledge on this factor. Rate of transpiration, quantity of crown, and root system all have a bearing, and there is probably adaptation to site. All we can at present do is broadly to state relative requirements. Amongst conifers, pines have the lowest requirement, and spruces probably the highest, while larches, Douglas fir, and *Tsuga* occupy intermediate positions. European larch requires considerable moisture for good development, Japanese larch requires more, while Sitka spruce is probably more adaptable to drier conditions than Norway spruce. The transpiration rates per unit weight of dry leaves is much higher for broad-leaved trees than conifers, but some, such as the birches, have a low leaf-weight per tree.

Nutrient Requirement. Our knowledge of this factor is also small. Ash analyses are open to criticism and culture experiments except for young plants difficult. There is, however, some degree of agreement on broad requirements, although it may yet be determined that individual species have special requirements for particular ions, such as ash for nitrogen. Again, pines have the lowest requirement, and, amongst conifers, Douglas fir perhaps the highest, with larches and spruce intermediate. Japanese larch appears to have a lower requirement than European, and Sitka spruce than Norway. Most broad-leaved trees, except birch, have a higher requirement than conifers.

Vigour. The variations in rate of growth have been mentioned under economic considerations. In addition, the inherently greater initial vigour of, say, Japanese larch compared with European, and Sitka with Norway spruce, is a factor in considering species for sites marginal for these genera.

Growth Period. This, particularly in its relation to damage by unseasonable frosts, is an important consideration. The short growth period of Scots pine, the characteristic of a continental rather than a maritime species, makes it our hardiest conifer. Corsican pine in this respect is less hardy; the larches cannot be used successfully on frosty sites, while, where a choice of spruces has to be made in frosty hollows, Norway is to be preferred to Sitka spruce, and *P. omorica* to both.

Shade Tolerance. This, together with relative rates of growth, is of importance in mixtures. These are not fashionable, but this factor has a bearing on what I have to say later. It may be noted that our natural forest communities, other than beechwood which does not occur in the hill country, is made up of relatively light-demanding species. It is interesting to speculate whether this is accidental or has a definite significance for the stability of soil fertility under our climatic conditions.

Root System. This has significance from several points of view. First, the formation of large blocks of pure spruce on relatively exposed sites may provide serious problems in the future. I think that we have been too complacent in this matter. Secondly, some type of podzol is probably the climax soil type on most of our hill country where the rainfall is under 50 inches. The deeper-rooting species have obvious advantages on this soil type. Thirdly, the

shallow-rooting species are much more sensitive to variations in ground-vegetation types than are deep-rooting species.

Resistance to Wind Exposure and Snow Damage. It is well known that this varies from species to species and in races within a species, and in some instance is the principal factor controlling choice. European larch is more sensitive to exposure than Japanese and Norway spruce than Sitka. Races of Scots pine show different reactions to snow.

Nature of the Leaf Litter. The importance of this subject has been emphasized in recent years: for example, the favourable nature of the leaf litter of broad-leaved trees, particularly birch, the liability of spruces to produce raw humus accumulations, and the relatively beneficial nature of Douglas fir litter. It is undoubtedly important, under the climatic conditions of most of our hill country and on many of our soil types.

Liability to Disease. The causes of health and disease in trees are as complex as in other organisms. Fortunately we have few killing diseases of trees in this country, but many of our stands are not healthy. Some of our diseases have been correlated with site characteristics, such as larch canker and frost, *Brunchorstia* on Corsican pine under cool humid conditions. Of perhaps greatest importance is the incidence of heart-rots. We know something about the relative susceptibility of different species, but little about the correlation with site. In general, however, conditions drier than the mean favour fungous diseases and insect pests.

We may sum up by saying that our economic tree species, native and introduced, conifer and broad-leaved, provide us with a wide range of characteristics, both as principal and accessory constituents of artificial forest communities.

Factors inherent in the Site.

Sites vary as widely as do species.

Climate. It has been well demonstrated that our climate as a whole is well suited to a wide range of trees, contrasting with the paucity of our native tree flora.

Rainfall is always ample for tree growth in the hill country, but there are wide variations, both in amount and distribution, from east to west and with altitude. Rainfall both itself and associated with temperature and evaporation has a definite influence on soil and vegetation types, on tree growth, and on the reaction of different tree communities on their sites. We have, however, little precise knowledge of these relationships. The general correlation between rainfall and evaporation criteria and peat moor development has been demonstrated, and we know that Scots pine does not retain its foliage so long in regions of high rainfall.

Temperature considerations are important in relation to choice of species. Climatically, a large part of our hill country belongs to the Northern Coniferous Forest rather than the Deciduous Forest of Europe. The summer temperatures are too low to permit good development of the principal con-

stituents of the latter, oak, beech, and ash, except on limited areas at the lower altitudes, although some may be useful for accessory purposes.

The micro-climate is frequently of great importance, particularly the incidence of unseasonable frosts which is influenced by topography and vegetation type.

Geology and Soil. Geology, although it is an imperfect tool, is frequently of great assistance in the choice of species. For example, the occurrence of quartzites is always a warning that plantability and choice of species should be very carefully reviewed, because of their intrinsic poverty in nutrients, while generally the basic igneous rocks enable a range of species to be considered.

Until the post-war period, the nature of the soil, and particularly its texture, was the principal criterion in the choice of species, as is shown by the older text-books. To-day, plantability is determined, and species are chosen for thousands of acres, with little, if any, soil study. We have been relying more and more on vegetation types. Our present confidence in vegetation types is, however, not due to a well-founded belief that they fully reflect site quality, but rather that during the past 20 years they have been correlated broadly with ease of establishment of different tree species. It does not necessarily follow, however, that ease of establishment is correlated with a soil type suitable for the full development of the crop. Moreover, the crop is going to react on the soil type. The developmental conception in soil science, as in ecology, has special significance in silviculture, and it is considered that greater attention should be given to soil types in choice of species than has been done in the recent past.

Topography. Topography is of importance both for its influence on soil type and local climate. For example, the degree of slope affects rate of podzolization and tendency to form pan. Aspect and altitude usually markedly influence local climate and choice of species. In the north of Scotland, larch is more suitable for the south facing than the north slopes and there is altitudinal zonation of vegetation types which has, for example, differentiated between the use of European and Japanese larches. There is also the frequent correlation between topography and unseasonable frosts.

Vegetation Types. The ground vegetation types can be considered from three different points of view:

(*a*) As a complete definition of the quality of the site.

(*b*) As a means, along with other factors, of correlating sites, for example a non-woodland with a woodland site.

(*c*) As a direct influence on local climate, competition, and through their leaf litter affecting ease of establishment.

With regard to the first, even the exponents of this view state that it is the vegetation types associated with mature or climax woods that fully reflect inherent quality. Our non-woodland vegetation types vary widely in status, history, and treatment, and their interrelationships are both complex and obscure in many instances.

In the second, more modest assumptions are made. A comparison is made between the vegetation types of non-woodland sites for which species are to be selected and the vegetation types on which woodlands of different species are growing; if canopy has closed the vegetation type adjoining, not in, the woodlands is the basis of comparison. This criterion is used along with others such as soil, exposure, &c., to determine the suitability of species for given types. The method is both practical and relatively safe, particularly when applied within a limited region where the natural climaxes and interference by grazing and burning are likely to have been similar. The available woodland data is generally limited at first, particularly for the newer exotics, but as afforestation proceeds, the plantations formed increase the data so far as ease of establishment is concerned. My view is that this consideration may thus be unduly influencing our choice of species.

The regeneration stage of a forest, whether by natural or artificial means, shows more varying responses to the complex factors of the site than do later stages. It is common knowledge that early irregularities in growth largely disappear later. One of these initial factors is the ground vegetation type. Apart from any question of it as an index of fertility, the nature of its own humus, its influence on local climate, and the effect of its competition all have an important influence, favourable or unfavourable, during the period until canopy closes, particularly on certain species of trees. It is the temporary elimination of the adverse influence of the vegetation that explains partly the benefit of turfing and ploughing, and the increase in growth after canopy closes. The improved conditions of drainage and aeration secured by these methods are important, but the quick establishment of canopy and the creation of different humus conditions is probably the principal requirement for continued growth on many of the difficult sites where these methods are being used.

To sum up, the site is the resultant of a complex set of factors. We should make as full use of all its indices as present knowledge permits. That knowledge is still limited, and it will be an additional advantage if, in planning our new forests, we can make it easy to utilize new knowledge, for example, the reaction of different crops on the site.

PLANTATIONS AND THE ECOLOGICAL IDEAL.

Even this incomplete outline of some of the criteria used in the choice of species shows how complex are the correlations that have to be made. It might be thought that with our still imperfect knowledge of so many of the criteria, a mixture of a range of species would be safest. It is known, however, that difficulty in subsequent management increases steeply with any increase of the number of species in even-aged mixture. There are, therefore, substantial reasons for reliance mainly on pure crops for initial formation. Will the resulting plantations meet the requirements that have been discussed? From another point of view, what ideal would the ecologist set before us? He would probably say that we should aim at self-reproducing forest commu-

nities in harmony with their environment. That may mean a great deal, and the giving full effect to it may be inconsistent with, say, economic considerations, even if we know how to do it. It is, however, worth while considering how we might proceed towards that ideal.

In the first place, emphasis is placed on communities rather than assemblages of individuals. Just as a vegetation type on a poor site is characterized by relatively few species, and a rich one by many, so it is in woodland communities, and the greater variety has favourable reactions on the site and its flora and fauna. To create the conditions necessary for a variety of species will generally require, however, a progressive improvement in the conditions on many sites other than the best. The first step is the creation of general forest conditions of soil and micro-climate. In many instances this can be done most easily by pure coniferous crops. There are exceptions, however, for example, on the upland heaths with strongly podzolized soils frequently with pan, which are now ploughed by tractor equipment when practicable. I am opposed to the use of pure spruce on such sites, although on economic and exposure grounds this is often indicated, if this crop can be grown successfully. The inherent site conditions are such, however, that a deep-rooting species such as a pine is probably essential at least in admixture with spruce even for establishment, without considering later requirements and the reaction of the crop on the site. Further, if birch or a similar broad-leaved tree can be introduced, say, by direct sowing, it will increase the likelihood of successful establishment. Where crops can be successfully established pure, however, this should be done as the first step. It is considered also that it is preferable, particularly on the poorer soils, that the pure crops should be such that subsidiary species can be subsequently introduced, either naturally or artificially, when conditions have been ameliorated. From the point of view of shade cast, the pines and larches will not cause serious difficulties in this connexion when the thinning stage is reached, but the spruces and Douglas fir may. The location of pure blocks of spruce should, therefore, be given special consideration. It is probable that pure spruce will be relatively safe on the more basic soils with adequate moisture, and in flush conditions, but elsewhere the site conditions are likely to deteriorate unless heavy thinning and the introduction of broad-leaved species are practicable. If Douglas fir is only located on the richer soils, its relatively good leaf litter may suffice to maintain, if not improve, the soil fertility. I believe also that this species has a future as a second storey tree for a considerable part of its life under light demanding species such as larch and perhaps pine.

What I am advocating is not systematic underplanting or uneven-aged forest. But, starting in most instances from pure crops, the species selected in the light of the criteria discussed, but preferably light demanders except on the richer soils, to progressively increase the variety of species and particularly to introduce broad-leaved species. This will be done, firstly, by making full use of thinning from an early age to improve soil and humus conditions, secondly, by protecting all trees and shrubs that come in naturally, and lastly,

the limited introduction where necessary of the more shade-bearing species. In this way we may create forest communities that are more and more in harmony with their environment. We should not only produce better crops in this way, but the resulting conditions should aid their regeneration, naturally or artificially. The difficulties are likely to arise in the poor sites, but there progressive improvement is particularly necessary.

Many of our afforestation areas are now reaching a stage when a beginning can be made in this second stage of the work.

ROOT-ROT OF SWEET CHESTNUT AND BEECH CAUSED BY SPECIES OF *PHYTOPHTHORA*

I. CAUSE AND SYMPTOMS OF DISEASE: ITS RELATION TO SOIL CONDITIONS

BY W. R. DAY

(Imperial Forestry Institute)

INTRODUCTION.

THE work upon which this paper is based was undertaken following the discovery of ink disease of Sweet chestnut in the New Forest in 1931. It so happened also that a beech stump was received from Somersetshire in January 1932 from which *Phytophthora cambivora*, one of the fungi causing ink disease, was isolated for the first time from this species so far as is known. This led to the examination of other diseased beech for the presence of *Phytophthoras* and to the further discovery of root-rot caused by these. It also led to the examination of beech dying on thin chalk soils. This part of the work was only carried sufficiently far to show that it was unlikely that *Phytophthoras* were a cause of disease on these sites. Some reference is made to this type of beech disease in order to compare it with root-rot arising from *Phytophthora* infection.

The identification of the species of *Phytophthora* was carried out for me by Mr. S. F. Ashby, Director of the Imperial Mycological Institute. Mr. G. R. Clarke kindly read the part of the paper dealing with soils. My thanks are due to both for their kindness and help.

PAST HISTORY OF THE PARASITES.

We are concerned here mainly with *Phytophthora cambivora* (Petri) Buis., *Ph. cinnamomi*, Rand, and *Ph. syringae*, Klebahn, as causes of root-rot of the Sweet chestnut, *Castanea sativa* Mill, and the common beech, *Fagus silvatica* L. Only one of these fungi, *Ph. syringae*, has been recognized for any length of time as a plant parasite. It was described by Berkeley in 1881 (2), under the name *Ovularia syringae*, as causing a disease of lilac leaves, and its principal importance in plant pathology has always been the relationship with this shrub. Lafferty and Pethybridge (14), and more recently Salmon and Ware (24), have isolated it from apple fruits, and according to Tucker (25) various species of *Citrus* are also among its hosts.

Phytophthora cinnamomi, Rand, was first described in 1922, when Rand (21) proved it to be the cause of stripe canker of *Cinnamomum burmanni*, Bl., in the west coast highlands of Sumatra. Its range of host has since been extended to *Oncidium* (25), *Persea* (25), rhododendron seedlings (1), heaths, and various

herbaceous plants (20), while Jackson and Crandall (13) record it, or a very similar *Phytophthora*, as causing the death of seedlings and transplants of *Pinus resinosa*. Tucker (26) also reports having received this fungus from *P. resinosa*, *P. silvestris*, *Quercus rubra*, and *Picea abies*.

Ph. cambivora (Petri) Buis. was discovered by Petri and first mentioned by him in 1916 (17) under the name *Blepharospara cambivora* n. sp. He proved that it could cause the 'Ink Disease' of the European Sweet chestnut. Since then it has been proved to have a considerable range of host. It has been found on walnut in Australia (5), in Italy (7 and 18), and North America (6). It will attack rhododendron seedlings (27 and 28), and Crandall (6), who regards this species as synonymous with *Ph. cinnamomi*, records it as occurring on *Taxus cuspidata*, *Picea excelsa*, *Robinia pseudacacia*, various pines, birch, larch, oak, Oriental planes, and American, Chinese, and Japanese chestnuts in Virginia, and to be capable of parasitizing Douglas fir. Tucker (25) also states that its hosts include many herbaceous species. In this country it appears to be the most widespread and important of the parasites causing ink disease. In the U.S.A., Milburn and Gravatt (15) believe *Phytophthora* root-rot on *Castanea* to have been prevalent at the lower altitudes from Maryland to Mississippi for some considerable time past. *Castanea dentata* and *C. pumila* are susceptible to it, while *C. mollissima*, *C. crenata*, *C. henryi*, and *C. seguinii* are resistant.

HABITAT AND CONDITIONS AFFECTING GROWTH.

The soil is the natural habitat of all three species of *Phytophthora*. They live in it as saprophytes and from it infect their hosts. They are all favoured by conditions of high humidity and are thus to be feared most in moist soils and during wet seasons. The optimum temperature for their growth is given as 15–20° C. for *Ph. syringae* (25); 25–30° C. for *Ph. cambivora* (25); and 20–30° C. for *Ph. cinnamomi* (1). The optima for the strains isolated in this country are between 20 and 25° C. All species grow more slowly at 30° C. There seems to be little information on the degree of soil acidity which favours the growth of these fungi. *Ph. cinnamomi* has been reported as growing best in soils of a pH between 5 and 7·8, and rather poorly where the pH is below 4·5 (1). This seems to indicate that the fungi probably grow well in moderately acid or neutral soils. The soils in which they have been found so far in this country fall within these categories.

SEASON OF ACTIVITY AS PARASITES.

In the case of *Phytophthora syringae* it has been shown that it is actively parasitic on lilac during the winter and early spring (3). Experience in the field in this country seems to show that *Phytophthora cambivora* is also active in chestnut and beech during this period, but isolations of all three species have been made during the summer and autumn. Thus, *Ph. cambivora* has been isolated in January, May, July, August, September, and October, *Ph. syringae* has been isolated in late September, and *Ph. cinnamomi* in late Sep-

tember and November. It appears, therefore, that *Ph. cambivora*, at least, exists in the host tissues as a parasite throughout the year, although it may be more active at one season than at another. In the field, *Ph. cinnamomi* has been found only on Sweet chestnut, and *Ph. syringae* only on beech. *Ph. cambivora* seems to occur quite commonly on both hosts.

SYMPTOMS OF THE DISEASE.

The symptoms of the disease are similar for all three species of parasite, but the aspect of diseased beech is slightly different from that of diseased Sweet chestnut. The parasite attacks the root from the soil. Small roots may be infected, as has been shown by Dufrénoy (8), but the parasite usually seems to enter the tree at or near the root collar. Judging by evidence in the field, no wound is required to permit its entrance, although in inoculation experiments the removal of the cork layer has so far proved necessary to successful infection. In the case of young developing roots, where no cork occurs, infection can take place in the absence of any injury. The parasite lives mainly in the cambium and inner cortex and spreads from the point of infection along the roots and usually some small way up the trunk. As far as the trunk is concerned, the fungus is most commonly found between the root buttresses, where its probable presence can be detected by the occurrence of dead or discoloured bark. No mycelium, however, can be seen in this except by microscopic examination.

The effect of the infection on the tree depends largely on the rate of spread of the parasite. This may be very fast when the tree rapidly becomes girdled at the root collar. It then dies within the first year of the appearance of obvious symptoms of disease, and it is unable to make any successful attempt at recovery by throwing up stool shoots. Very large trees may be affected in this way. In the case of Sweet chestnut, this rapid progress of disease is signalized by the wilting of the leaves, those on the top of the tree being most affected. This rapid form of the disease associated with the wilting of the leaves has never been observed on beech.

Trees which take more than one year to die after the appearance of subaerial symptoms of disease may be very variously affected. This applies especially to chestnuts. Some trees merely produce extremely dwarfed leaves and flowers in the next year and then die. Others, and this is usual with beech, show early yellowing of the leaves, which then turn brown, either over the whole or a part of the crown. This condition may continue for several years, the dying of the crown taking place piecemeal. The leaves on such trees do not seem to be appreciably dwarfed, but at the base of the trunk a zone of dead or dying bark can be found spreading up from the soil level. From this affected bark there may be an exudation of fluid, which is blackish in the case of chestnut but with beech only becomes markedly discoloured after exudation. These exudations are a common feature of the disease, but are also quite commonly absent. It is to be noted that a similar exudation may occur on beech affected by a disease due to other causes, as is described later.

Trees in this chronic condition seem to be fated to die in most instances, but sometimes they undoubtedly recover. In this case an actively developing callus grows beneath the dead bark, and roots are sent down from its edge to the soil below. This formation of adventitious roots has not been noticed in beech. The formation of stool shoots is also common with partly dead chestnuts, but has not been observed with beech.

The blue-black staining of the bark of roots and of the soil surrounding them, which has given rise to the name 'Ink Disease', has been observed only with chestnut. It varies considerably in intensity on different soils and owes its origin to the production of ink by the combination of iron in the soil with tannin released from the plant on the death of the bark. Because of the failure of the inky coloration to occur generally, it is felt that *Phytophthora* root-rot is a better general term than 'Ink Disease'.

ISOLATION OF PARASITE.

The parasite may be isolated with ease from diseased tissue in the right condition. Examination of infected trees will show that when the disease is in active progress the affected bark between the root buttresses, or on the roots, is either dark brown in colour, when it is plainly dead, or is much lighter in colour, but appears as if sodden with water. When in the latter condition, the bark is in process of being killed by the parasite, and it is from such bark that isolation can be made with ease, whether from chestnut or beech. Bark in this condition is, naturally, found between the dead darkly discoloured bark and that still healthy. It is extremely difficult or impossible to isolate the parasite from bark which is already dead and darkly discoloured. However, many other fungi and also bacteria can be obtained from it. When collecting material for the isolation of the parasite, it was found to be a great advantage to bring the infected bark to the laboratory attached to the wood beneath. The parasite lives mainly in the inner bark; if the bark and wood are separated, the fungus is liable to die or to be swamped in culture by saprophytes which contaminate the exposed tissues.

COMPARISON OF *PHYTOPHTHORA* ROOT-ROT WITH DIE-BACK AND CANKER OF BEECH ON SHALLOW CHALK SOILS.

By a superficial examination of beech in the field it is often difficult to distinguish between trees affected with *Phytophthora* root-rot and those dying back owing to other causes. Actually it is impossible to tell with complete certainty whether any tree is affected with *Phytophthora* rot until the parasite has been isolated. When beech are dying back on well-drained dry sites, such as not uncommonly happens on Chalk Downs, they not infrequently show patches of dying bark at the base or on the lower part of the trunk. This diseased bark sometimes goes down to soil level, as with *Phytophthora* root-rot, but it occurs commonly in patches surrounded by healthy bark. Frequently an exudation of sap flows from these. Such isolated patches have never been observed with *Phytophthora* root-rot, but when they are extending water-sodden bark occurs which is similar in appearance to that seen with it. The

exudation from these patches results from an accumulation of clear liquid behind the affected bark. It has sometimes been suggested that the patches start from wounds, such as shot wounds, but a careful examination of an early stage reveals no break whatever in the bark.

A number of fungi have been isolated from the advancing edge of these patches, *Bulgaria polymorpha* and especially *Nectria* spp. being the most common. A *Phytophthora* has never been recorded. No attempt has been made to trace the origin of this phenomenon or the cause of the commonly associated die-back. It is markedly most severe, however, on thin poor soils over hard chalk, and, at least when die-back of the crown occurs, is always associated with a severe die-back of the root. The root also seems to be quite free from *Phytophthoras*, but is infected not infrequently by *Ustulina vulgaris*. This disease of beech, so common on certain chalky soils, is of considerable pathological interest. It is to be noted that the trees affected frequently show chlorotic foliage. The chlorosis shows as soon as the buds burst, and there is every indication that the trees are suffering from a deficiency disease. *Phytophthora* root-rot is not marked by this type of chlorosis. When the leaves of a beech affected by *Phytophthora* root-rot are yellow over the whole of the crown, it is a sign that the disease is far advanced and that the tree will die.

SOIL CONDITIONS AND INCIDENCE OF INFECTION.

It has generally been recognized that there is a relationship between incidence of infection with *Phytophthora* root-rot and the moistness of the soil. Thus Petri (17) concludes that an impermeable subsoil and a high clay content predisposes to infection. Rand (21) states that infection of *Cinnamomum burmanni* with *Ph. cinnamomi* is particularly severe in badly drained inland plantations in Sumatra. Moquer (16) states that in France ink disease of Sweet chestnut is limited to woods within reach of sea (i.e. moisture laden) winds, and that it is most prevalent on schistic compact clay soils. White (27 and 28) found that, in inoculation experiments with *Ph. cambivora*, rhododendron plants on humid soils were the first to wilt, and he recommends, as one of the control measures, the avoidance of excessive irrigation. An examination of the soils on which *Phytophthora* root-rot has occurred in this country shows that there is a similar correlation between the moisture content of the soil and the occurrence of infection. Such moist soil conditions are usually, but not necessarily, associated with the occurrence of impeded drainage near to the soil surface. The occurrence of such impeded drainage may be due to a high water-table, but the texture of the soil is also a factor of great importance. Thus, the soil may drain with difficulty because of its compactness, as with some of the very fine-textured silty sandy soils which occur in the Hastings Beds in the Weald (10 and 12), or it may be water retentive because of its clayey nature.

The characteristic feature of soils with impeded drainage is the presence in the profile of a layer which has a mottled colour owing to what is generally believed to be a local reduction of ferric iron to a ferrous condition. All the

soils examined where disease was present showed such a mottled or 'gleyed' horizon, with the exception of a heavy clay soil over limestone brash (Example I, p. 112). The more severe the incidence of disease, the more marked were the signs of impeded drainage. The occurrence of a gley horizon is an indication that periods occur during which this layer of the soil is full of water and in an anaerobic condition. The reduction of iron takes place during these periods and is especially to be noticed along root channels or along the structure fissures which, in heavy subsoils, are where root development principally takes place.

The main value of a gleyed horizon as regards root development is that it provides a reserve rooting-space for periods when the upper well-drained layer is dry. The conditions which prevail in a gley prevent permanent deep rooting, however, and wherever they exist root disease seems particularly liable to occur. Their importance in relation to *Phytophthora* root-rot is probably indirect, through their effect on the general health and vigour of the trees.

EXAMPLES OF PROFILES IN DISEASED AND HEALTHY WOODS.

In order that the importance of drainage and soil texture may be better appreciated, the following examples are given of soils in healthy and diseased woods. These soils are described from field observations only. The spring of 1938, during which the soils were examined, had been very dry over the whole of the area covered.

Soils in Hemsted Wood, Kent.

The soils which were examined in Hemsted Wood are, apparently, all derived from Tunbridge Wells Sand, one of the Hastings Beds in the Weald. They are very fine-grained soils in which the clay content is not very high, but which contain a large proportion of fine sand and silt, and very little coarse material (10 and 12). These soils tend to have very little structure. Fertility seems to be closely correlated with drainage, and chestnut coppice has not been planted on the more infertile types. Rain had fallen about three days before the profiles were examined, otherwise the weather had been dry for some considerable time.

(A) Taken under diseased chestnut coppice, 20–25 feet high, at the edge of a clearing made by the death of stools from *Phytophthora* root-rot.

A_0 A sparse litter of chestnut leaves. No mor or crumb structure.

0–1·5 in.	Black humus-stained soil, sharply defined from
1·5–2·25 in.	Compact purple-grey fine sand, fairly sharply defined from
2·25–17·25 in.	Bright brown moist fine silty loam, rather compact and with free moisture in places; merging into
17·25–37·75 in.	Wet, hard, compact silty clay, mottled light grey and brown; merging into
37·75 in. +	An unknown depth of light-grey silty clay, hard, compact, and impermeable.

Ground vegetation. Almost nil under coppice. In the clearing nearby the following plants were most common: bracken (a.),[1] brambles (a.), bluebells (v.a.), *Calluna vulgaris* (l.a.), woodsage (f.-a.), foxgloves (f.-a.), honeysuckle (f.-a.). The growth of all was rather poor.

Aspect. South to South-east.

Slope. Moderate to gentle.

(B) Taken about 200 yards from (A) under good quality healthy coppice 35–40 feet high.

A_0 A good litter of chestnut leaves.

0–2 in. Loose light grey-brown sandy loam, having a crumb structure and defined fairly sharply from

2–15 in. Bright brown fine silty loam of loose consistence and merging into

15–31 in. Lighter coloured brown silty loam of fairly loose consistence, with sandstone fragments 3–4 in. across, and occasional nodules 2–3 in. across, of heavier soil mottled fawn and brown; merging into

31 in. + An unknown depth of moist sandy clay strongly mottled grey and brown, and containing frequent sandstone brash fragments.

Ground Vegetation. Bluebells (d.), mosses (l.a.). No *Calluna* occurred in the ride on this soil, but only grasses.

Aspect. Easterly.

Slope. Moderate to gentle.

This soil is much deeper and better drained than (A), and the upper layers were markedly drier. The growth of the coppice showed, also, that it is more fertile. Other places in which disease occurs at Hemsted have similar soil profiles to (A), but sometimes the gleyed horizon is much nearer to, or actually reaches, the soil surface. Rushes and tussock grass then occur when the woodland is cleared, and ling is always present. The change from diseased to healthy areas takes place quite abruptly. Soils composed of material similar to (B) may bear diseased coppice if so situated that they receive drainage from higher ground and are, accordingly, often wet. Under such circumstances the drainage is impeded much nearer to the surface than in (B).

Soils near Petworth and Midhurst, Sussex.

In the vicinity of Petworth and Midhurst, *Phytophthora* root-rot occurs among Sweet chestnut on heavy soils derived from Weald Clay or Atherfield Clay, but is absent on light well-drained soils derived from the Hythe Beds of the Lower Greensand. It becomes apparent here that fertility of soil is in itself no guarantee against infection, but that dryness is the deciding factor with regard to this. The following are examples of typical soils. Some idea of the composition of these soils can be obtained from the memoir by Hall and Russell (12). As a rule they appear to be only of very moderate fertility from an agricultural standpoint.

(C) A mixed woodland of Sweet chestnut and Sessile oak standing on Atherfield Clay. The oak were very fine trees. The chestnut were dying of *Phytophthora* root-rot.

[1] v. = very; a. = abundant; d. = dominant; f. = frequent; o. = occasional; l. = locally.

A_0 A good litter consisting mainly of oak leaves.

0–3·25 in.	Dark brown loam with a good crumb structure; merging into
3·25–11·75 in.	Crumbly cloddy heavy dark brown loam with many small black concretions, merging into
11·75–25·75 in.	Cloddy heavy clay, changing in colour from brown mottled with grey at the top to grey sparsely mottled with brown at the bottom of the exposed section.
	Most roots in the top 12 inches.
	No stones.

Ground vegetation. Sparse; brambles (a.), ivy (a.), holly (o.), hawthorn (o.), *Pyrus torminalis* (o.). The growth of the oak indicates that this is a fertile forest soil.

Aspect. Southerly.

Slope. Gentle.

Similar profiles are also to be observed on the Weald Clay. The presence of a good crumb structure in the upper layers of the soil seems to have a moderating influence on the progress of disease but is no guarantee that it will not occur. In the following example, (D), there was no crumb structure and the disease was strikingly severe.

(D) Mixed high forest of oak and Sweet chestnut 40–50 feet high and raised from coppice shoots. The chestnut were badly diseased.

A_0 No litter.

A_1 A slight layer of black mor.

0–2 in.	Dark grey-brown heavy loam, fairly loose in consistence and merging into
2–8·5 in.	Dark-brown loam mottled with lighter brown; slightly compact and containing many dead roots of diseased trees.
8·5–12·25 in.	Bright brown moderately heavy loam, mottled with fawn; cloddy structure and rather compact, merging into
12·25–24 in. +	Compact cloddy clay, fawn mottled with brown; many dead fine rootlets occurred.
	Most roots occurred in the first 17 inches.
	No stones.

Ground vegetation. Very sparse and consisting of ivy and mosses.

Aspect. North-west.

Slope. Moderately steep.

The important features of this soil are its shallow depth without signs of impeded drainage, its compactness and absence of crumb structure.

Most of the healthy chestnut coppice in this district stands on the Lower Greensand hills which constitute the outcrop of Hythe Beds. No case of *Phytophthora* root-rot has been found on these hills. As a rule the soils are shallow and stony and grow much shorter oak than a heavy loam such as (C). They seem, however, to be well suited to the growth of chestnut. The quality of coppice is related to depth of soil. Drainage is completely free and the

water-table beyond the reach of tree roots. The following example represents one of the deeper and better soils.

(E) Chestnut coppice of good quality, 12–20 feet high.

A_0 A good litter of chestnut leaves.

A_1 A very slight layer of mor.

0–6·25 in.	Dark grey-brown light sandy loam of loose consistence, with very few stones, merging into
6·25–20 in.	Slightly lighter coloured grey-brown light sandy loam of loose consistence, with large and small sandstone brash fragments, lying over
20 in.+	An unknown depth of sandstone brash with a sandy loam in the interstices.

Ground vegetation. Bluebells (v.a.), dog's mercury (a.), purple orchis (o.). In an adjacent hedgerow there were mature oak 50 feet and holly 25 feet high. On other similar sites, foxgloves and grasses took the place of dog's mercury.

Aspect. Flat.

Slope. None.

Situation. On a hill-top.

Soils in the New Forest.

Sweet chestnut occurs in the New Forest mainly in mixed high forest associated with oak, beech, and Scots pine. Its quality varies considerably but tends to be poor on heavy shallow soils where drainage is difficult. The oak on such soils is often stag-headed and in some cases is dying, while the Sweet chestnut has been generally infected with *Phytophthora* root-rot. Beech is frequently the healthiest of the dominant broad-leaved trees. The poor condition of the oak is to be accounted for in part by defoliation and mildew attack. Inoculation experiments show that oak is less susceptible to *Phytophthora* than beech, which is fairly healthy here. Accordingly, it is unlikely that *Phytophthora* root-rot is an important cause of the die-back of oak.

(F) Taken in Rhamnor Inclosure. A mixed and rather open stand of poor quality, consisting of Sweet chestnut together with oak, beech, pine, and larch. There is an open underwood of sycamore, birch, hawthorn, pine, and holly. *Phytophthora* root-rot has been prevalent here for at least twelve years. It became epidemic after the clearing of a large part of the high forest. The water-table rose in the cleared areas, and in the remaining strips root-rot became virulent. Only the chestnut was affected so far as is known.

Geological formation. Clay-flint drift over Headon Clay.

A_0 A rather sparse litter, mainly of chestnut leaves. No mor; no surface crumb structure.

0–2 in.	Dark grey-brown sandy loam showing slight grey leaching in places, and with angular flint pebbles. Sharply defined from
2–8 in.	Sandy clay, deep fawn mottled with grey and bright brown and with numerous angular flint pebbles. The larger live roots are in this layer and the top of the one beneath. Structure cloddy and fairly loose. Merges into

8–13·5 in.	Light brown sandy clay with fawn and bright brown mottling; cloddy and rather compact; contains some angular flint pebbles and stones up to 2½ in. across; fairly moist and contains many dead fine roots. Merges into
13·5–25·5 in.	Blue-grey moist cloddy sandy clay mottled with brown; angular flint fragments and pebbles numerous; fine roots very numerous but dead; some roots ½ in. diam. but dead. The blueing was very marked along the dead root channels, and water flowed out of these. Merges into
25·5–32·5 in.+	Plastic and apparently structureless blue-grey clay mottled with bright brown; small flint fragments numerous; fine dead roots numerous; blueing of root channels very marked.

Ground vegetation. Bracken (l.d.), brambles (f.–a.), ivy (l.f.), honeysuckle (l.f.), *Polytrichum commune* (l.d.–a.), lichens (l.a.), woodsage (l.f.), *Agrostis* (f.–l.a.), tussock grasses (o.). Rushes were abundant in an open drain a few yards away.

Aspect and Slope. Flat.

Situation. Hill-top.

The two last layers in the profile had a marked faecal odour. The incidence of root-rot on this soil moderated during the dry summers which occurred from 1933 to 1935, and has not been so severe since. In the meantime, the plantations in the cleared areas have grown up and the soil is generally drier.

Example (G), following, was taken from Clumbers Inclosure at a place where Sweet chestnut of good quality grew. One or two of these were slightly affected by disease. The following profile was dug near the site where these grew.

(G) Open coppice of Sweet chestnut with oak standards in groups, on the site of a previous stand of mixed oak and chestnut high forest.

Geological formation. Barton Sand.

A_0 A fair litter consisting mainly of oak leaves.

A_1 A very thin layer of mor.

0–2 in.	Dark grey-brown sandy loam of loose consistence. A leached layer up to 4½ in. deep occurs locally. Angular flint pebbles occur. Fairly sharply defined from
2–24 in.	Brown light sandy loam of soft consistence. Local patches of fawn and light brown mottling occur. Merges into
24–34 in.	Red-brown, somewhat compact, clayey sand. Merges into
34–46 in.	Compact clayey sand, brown with fawn and bright brown mottling; a jointed columnar structure was suggested. Merges into
46–48 in.+	Rather compact clayey sand, mottled grey and bright brown. Roots were well distributed down to 2 feet 6 inches; fine roots were common to the bottom of the profile. Moisture increased with depth, the lower layers being moist but not wet.

Ground vegetation. Brambles (d. and moderately vigorous), rushes (a.), ivy (f.), wood sorrel (f.), bluebells (f.), *Agrostis* (l.f.), mosses (f.). Bracken was dominant and grew up to 6 feet 6 inches high on adjacent sites where healthy chestnut stood previously. The soil was less moist there.

Aspect. Southerly.

Slope. Gentle.

Situation. On the mid-slope of a gentle hill.

The next example is of a soil with a very deep gleyed horizon and with practically no depth of permanently well-drained soil, from a site in Brick Kilns Inclosure on which Sweet chestnut has suffered severely from root-rot and on which oak is also in bad condition.

(H) In a clearing made some 3 years ago in high forest of oak, Sweet chestnut, beech, and pine.

Geological formation. Clay-flint drift.

No litter or mor. A slight sign of worm activity.

0–2·5 in.	Dark grey-brown sandy loam, with some angular flint fragments and abundant grass roots; sharply defined from
2·5–8 in.	Grey-brown clayey sand with very slight grey mottling; angular flint fragments occur; structure cloddy with a fairly loose consistence; many roots; this merges into
8–13·75 in.	Stiffer grey-brown clayey sand slightly mottled fawn and bright brown; structure cloddy with a fairly loose consistence; angular flint pebbles numerous; fewer fine roots occur than above. This merges into
13·75–17·5 in.	Moist sandy clay, light grey-brown mottled fawn and bright brown; structure cloddy with a fairly loose consistence; flint pebbles numerous; some black-brown concretions occur. This merges into
17·5–31·5 in.	Moist sandy clay, fawn mottled bright brown; compact, and with a cloddy structure; markedly blue-grey along dead root channels; many dead fine rootlets. This merges into
31·5–46·5 in.+	Moist sandy clay, compact, and with a cloddy structure. A little free water occurred. Many very small angular flint fragments occurred, and many black-brown concretions. There were many dead fine rootlets, the channels of which were markedly blued. The roots in the deeper layers appeared mainly to be those of the old stand.

Ground vegetation. Grasses (a.), including *Poa*, *Agrostis*, and *Deschampsia caespitosa*; brambles (f.–l.d.), ivy (l.a.), honeysuckle (l.a.), mosses (a. beneath herbage), *Carex* spp. (f.), *Potentilla* (f.), *Viola* (f.), woodsage (f.). The vegetation was not luxuriant in growth.

Aspect. Southerly.

Slope. Gentle.

Situation. An upper slope.

This profile is typical of a number of sites in the New Forest on which disease has occurred, in so far as impedance in drainage is concerned. In one inclosure, for example, many diseased chestnut have been thrown by wind, and it can be seen that only the surface root-system, in the shallow well-drained top soil, is alive. In this place the gleyed horizon frequently reaches to the soil surface and is always near it. The progress of the disease was

undoubtedly retarded here during the dry summers from 1933 to 1935, and has not been so rapid since.

The association of *Phytophthora* root-rot with impeded drainage persists in other areas where this disease has occurred, e.g. in North Devon on the Culm measures, in Somersetshire on Trias and Lias clays, and in Herefordshire on heavy Old Red Sandstone soils. In all cases the character of the soil is such that the A horizon is water retentive. Occasionally root-rot occurs on a soil in which impeded drainage is absent and the clayey water-retentive character of the soil is the important factor. An example of such a soil may finally be given:

(I) A mixed stand of beech, European larch, Scots pine, and oak, 35–40 years old and about 45 feet high.

Geological formation. Lower Lias limestone.

A_0 A thick litter of leaves and needles.

0–3·5 in.	Dark grey-brown heavy clay, wet, with a good crumb structure, merging into
3·5–10 in.	Wet, loose, cloddy crumbling brown clay with many limestone fragments, merging into
10–34 in.+	Well-fissured laminated limestone. A near-by pit shows this to be about 3 feet thick, with a clay stratum beneath it which temporarily holds up water.

Ground vegetation. Almost nil; *Arum maculatum*, fine large primroses, and mosses occurred.

Aspect and Slope. Flat.

Situation. On a hill-top.

It was stated that there had been no appreciable rain for some weeks up to the time of examination.

At this place, a few beech had been infected by *Phytophthora cambivora*. The infection was restricted to the root collar so that the affected parts could be exposed and removed easily; they did not pass below the first layer mentioned above. Trees so treated recovered.

ROOT DEVELOPMENT IN RELATION TO DISEASE.

The profiles described above illustrate the relationship between the moisture-retentive character of the soil, ease of drainage, and infection with *Phytophthora* root-rot. The severe attacks of this disease have always occurred on shallow, heavy, or compact soils with impeded drainage in the subsoil. The greater the depth of drained soil, the freer the drainage, and the less water retentive the soil, the less likely is infection to occur. The close association between impeded drainage and severity of disease leads one to ask whether the conditions which accompany impedance may not in themselves be a cause of disease, and, at least sometimes, predispose the host to succumb to the parasite by causing in it a state of debility, and perhaps by providing an abundance of dead roots on which the parasite can thrive previous to successful infection taking place. No completely clear view of this matter can be reached until

further research has been carried out into root development in the soil types under discussion, but sufficient is known to make certain conclusions possible.

THE DISTRIBUTION OF MOISTURE IN THE SOIL.

The main variable factors controlling root development in the soils under discussion are air and water. Clarke (4) has pointed out that in Brown Forest soils, such as these are, one has the phenomenon of a wet zone in the A horizon over a drier zone in the B horizon, superimposed on the permanently wet zone of the ground water. If these soils have a gley horizon, a more or less permanently wet zone may be found at the base of this layer. Rogers (22), and Rogers and Vyvyan (23) excavated the roots of apple trees growing in heavy soils with a gleyed horizon. These trees grew in grass-covered orchards standing, in the one instance, on a heavy colluvial soil over Atherfield clay, and in the other on a heavy clay derived from Weald clay. The excavations were made in November and April respectively. The determinations of soil moisture made in connexion with this work showed that the surface layer of soil, in which the grasses mainly rooted, was very much wetter than that lying immediately below. Under the more complete canopy such as exists either in high forest or chestnut coppice, the absence of a grass sward and the lower rate of evaporation from the soil surface, as compared with the more exposed orchard soil, would tend to maintain a high moisture content in the surface layer more evenly and for longer periods, while the better soil structure which tends to develop would assist drainage and have an influence in the opposite direction. The resultant effect on the lighter and drier soils, such as Examples (B) and (E), is to maintain conditions which are favourable for root development but too dry for the serious development of the fungus. But on compact or clayey soils the moisture content of the A horizon remains so high that fungal development is favoured. In this way an explanation is obtained of the presence of infection on a heavy but well-drained limestone soil such as Example (I), as well as on soils with impeded drainage near to the surface, such as Examples (A), (F), and (H), for it is well known that the root-infecting *Phytophthoras*, with which this paper is concerned, commonly effect an entrance into the host in the part of the root lying within the A horizon, or upper humus stained layer of soil.

THE GLEYED HORIZON IN RELATION TO INFECTION AND ROOT DEVELOPMENT.

The main factor affecting root development in a gleyed horizon is the periodic occurrence of anaerobic conditions when the soil in this layer is more or less saturated with water. The lower part of the horizon endures such conditions for longer periods than the upper, and because of this the root development in it tends to be poor or absent. Thus, a level is reached below which roots become uncommon because of the long periods when growth is impossible. Examples of this are given by Rogers and Vyvyan (23) and also by Day (8). These conditions result in a more or less shallow type of root system on the lower edge of which root action and development are interrupted

periodically by the occurrence of anaerobic conditions. The effect of this on the growth of the tree depends mainly on the depth to which drainage is permanently good and on the fertility of the soil. If the soil has deep freely draining upper layers, as e.g. in Example (B), no ill effect is ever likely to be experienced. If, however, these layers are compact, slowly draining, or relatively shallow (Examples (A), (D), and (F)), times must occur when a great part of the root system is unable to function properly, when the soil is saturated with water. There seems to be little doubt that the dying back of Sweet chestnut (as well as of other species of tree) on shallow soils with a gleyed horizon is to be explained in part in this way. If ink disease is prevalent, then such soil conditions will act as contributory factors, helping to bring about the death of infected trees. The increase in rate of death of infected trees which takes place during wet seasons may, thus, arise in part owing to a state of debility caused by adverse physical conditions in the subsoil as well as to the more favourable conditions for the development of the parasite. The work of Furneaux and Kent (11) on 'The Death' of fruit trees actually provides examples of trees dying simply because of the temporary water-logging of soils in which drainage in the subsoil is impeded. There is no reason to assume that Sweet chestnut or beech is any more resistant to anaerobic soil conditions than are fruit trees.

THE CONTROL OF DISEASE IN RELATION TO SOIL CONDITIONS.

The evidence brought forward in this discussion leads to the conclusion that in the southern and western parts of England chestnut grown on soils which remain moist for long periods is very liable to infection by *Phytophthora*. On the other hand, the risk of such infection seems to be absent on light well-drained loams. These are relatively dry soils, both in the A and B horizons. Drainage may be completely free on such soils, as in Example (E), or there may be a deep, loose, well-drained layer of soil over a gleyed horizon, as in Example (B). It is plain, therefore, that the control of *Phytophthora* root-rot depends largely on limiting susceptible species to soils which do not favour the development of the parasite. Anything which favours the drainage of a water retentive or wet soil tends to lessen the incidence of disease. The development of a good crumb structure in a heavy soil acts in this way. Nevertheless, if a soil with such a structure remains wet (Example I), disease is liable to occur.

It has sometimes been asked why chestnut has only been attacked by *Phytophthora* root-rot within recent years. Actually, there is no evidence that this disease has never been active before. The parasites have only been recognized since 1916, and other explanations would have been found for disease occurring before then. It is possible, however, that on acid soils of but moderate fertility and low base status with a tendency to compactness and with impeded drainage, such as Example (A), the continued and frequent cropping of coppice may result in a serious depletion of the fertility of the soil owing primarily to the removal of mineral food substances, but possibly associated

also with an adverse change in humus conditions. The consequence of this would be a degradation of the soil structure and a rise in degree of impedance of drainage. Such a development would favour the occurrence of root-rot, firstly by increasing the periods when anaerobic conditions occur, and secondly by increasing the general degree of wetness of the soil. There would thus be an increase in the general liability of roots to die, both from non-parasitic causes and from *Phytophthora* root-rot. The acceptance of this hypothesis as generally true leads to the conclusion that chestnut coppice should be kept to the more fertile soils, providing they are sufficiently dry. This is the conclusion to which field observations also lead.

Beech is less susceptible to infection than is Sweet chestnut, but is liable to become diseased under the same conditions as that species. So far as is known, no epidemic outbreak of infection has occurred among beech, and, as mentioned above, this species has apparently remained free from any sign of infection in areas where many Sweet chestnut have died.

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THE DEPLETION OF STARCH FROM TIMBER IN RELATION TO ATTACK BY *LYCTUS* BEETLES

III. A SECOND EXPERIMENT UPON THE GIRDLING OF STANDING OAK TREES

BY E. A. PARKIN

(Forest Products Research Laboratory, Department of Scientific and Industrial Research)

INTRODUCTION.

A PRELIMINARY experiment in which four standing oak trees (2) were girdled indicated that this method of rendering the sapwood free from starch, and therefore immune from *Lyctus* Powder-post beetle attack, had practical possibilities. Too few trees were treated, however, to ascertain whether the results were reliable and to give an idea of the cost and practicability of carrying out the girdling operation on a large scale. A second experiment was, therefore, planned to include these points and to discover, if possible, the rate at which the starch was resorbed. The present paper gives the results of this investigation and is the third contribution to a series concerning the presence of starch in timber and methods of causing its resorption.

MATERIAL.

The preliminary experiment was carried out on an estate too distant from the Laboratory to allow regular observation of the trees, and a nearer site was therefore sought. Through the co-operation of Messrs. Henry Brown & Son, Ltd., Bute Sawmills, Luton, Bedfordshire, twenty standing oaks (*Quercus robur* L.) in Newland's Wood, Beechwood Park Estate, near Markyatestreet, Herts., were placed at the disposal of the Laboratory for girdling. Four additional trees served as controls. The trees were selected from a stand of oaks about 80–100 years of age, mixed with a few elm and ash saplings. The trees were girdled round the main stem just below the crown on 22 and 23 April 1937, at which time there were no signs of buds bursting.

General data on the trees are given in Table I.

TREATMENT.

Twenty oaks were girdled, as directed, by a firm of felling contractors. A 6-inch ring of bark was removed just below the lowest main branches by chopping through the bark with an axe, then riving it off with a barking iron. A notch, $\frac{1}{4}$ to $\frac{1}{2}$ inch deep, was cut round the centre of the exposed sapwood with the aid of a mallet and V-shaped hand turnery chisel, in order to ensure that the continuity of the phloem and cambium was interrupted. The bark did not peel easily, and it would, therefore, be preferable to carry out girdling

later in the year when the sap is running more freely. In an earlier experiment (2) timber exposed at the girdles became infected by fungi causing stain and decay. The girdles on ten trees were, therefore, given a liberal brush application of coal-tar creosote to ascertain whether this would act as a preventive.

TABLE I. *General data on experimental and control trees*

Treatment.	*Tree No.*	*Girth at 4 ft.*	*Length to girdle.*	*Volume to girdle†*	*Sapwood.*	
					Width.	*Annual rings per inch.*
		in.	ft.	cu. ft.	in.	
Controls	435	55	..	..	1·00	24
	461	79	..	..	1·43	15
	487	78	..	..	1·73	12
	505	65	..	..	1·00	24
Girdled	413*	82	17	53	1·10	17
	431	63	19	33	1·27	18
	433	45	23	18	0·91	24
	434	63	20	35	0·85	18
	437*	59	16½	26	1·10	18
	438*	69	16	35	1·15	18
	453*	55	17	23	1·03	23
	454*	74	16	41	1·02	18
	455	62	22½	37	1·20	20
	457*	72	17½	41	1·30	18
	462	81	17	51	1·53	12
	463*	73	16½	40	1·55	14
	468*	53	16	20	0·95	26
	469	75	19½	49	1·65	12
	481*	70	19	42	1·25	14
	488*	60	18	29	1·70	15
	498	68	23	45	1·42	17
	499	75	22½	55	0·72	17
	502	67	23½	45	1·10	17
	503	49	22½	22	1·28	22

* Girdles painted with coal-tar creosote.

† Based on a taper of 4 in. of girth per 6 ft. of length, and deducting 10 per cent. for volume of bark.

The treatment was undertaken by three men, two carrying out the girdling and the third helping to move and steady the ladders. The total working time amounted to 15 hours. The volume of the timber below the girdles was about 740 cubic feet and at an average labour charge of one shilling per hour per man the price of this timber is increased by 0·73 pence per cubic foot. The girdling was carried out much more quickly and neatly as the men became more experienced, so that the cost per tree of treating a larger number would have been less. By ringing the trees just below the first main branches, about one-half the final length of the log was included in the treatment.

By means of an increment borer, samples of sapwood were removed at breast height from each of the control and experimental trees. Borings, removed at least 3 inches vertically or horizontally from any others, were taken monthly from two girdled (Tree Nos. 413 and 462) and two control trees (Tree Nos. 435 and 487) to observe the progress of starch depletion, and a watch was kept on the foliage of the experimental trees to determine whether any difference, resulting from the girdling, could be detected.

RESULTS OF GIRDLING.

(1) *Effect on Growth of Trees.*

No difference was noted between the experimental and control trees until August, when the girdled trees had many more epicormic twigs on the trunk than the controls, and the leaves of these small branches were white with the mildew fungus *Oidium quercinum*. Very few non-girdled trees showed more than an occasional epicormic branch, and the leaves of these were mostly free from *Oidium* infection. The leaves of the girdled trees began to turn yellow at the end of September, changed to brown, and started to fall in October, and had all fallen by the end of November. The corresponding changes took place about one month later on the non-girdled trees. When the trees were examined after felling, callus growth was visible on the edges of most of the girdles, but had nowhere covered the barked area for a distance greater than one inch.

On 22 April, the date of girdling, production of spring-wood vessels had just commenced, and at the next examination, one month later, the ring of springwood vessels was complete. In the ringed trees, below the girdle, further development of the annual ring was arrested and summerwood was not laid down. In the controls and above the girdles of the treated trees a normal annual increment of springwood and summerwood was formed.

(2) *Effect on Susceptibility of Tree before Felling to Fungus and Insect Attack.*

In order to minimize damage to the timber, samples were taken only in the form of borings through the sapwood. This made it difficult to determine the extent of fungal attack, but by chopping off some of the bark in the vicinity of the girdles it was possible to observe that a brown staining fungus was present in the sapwood to a depth not exceeding $\frac{1}{2}$ inch and for a distance of 3–12 inches above and below the girdle. The application of creosote had not prevented entry of the fungus. Soon after felling, the logs were cleft into fencing pales and the foreman in charge of this work in Messrs. Brown's yard reported that the amount of stain in the logs was insignificant.

No evidence of insect attack was seen in the bark or wood of any of the trees.

(3) *Effect on Starch Content.*

The starch grade of each $\frac{1}{10}$ inch of sapwood was recorded for each boring according to the grades 0–6 defined by my colleague, Mr. E. W. J. Phillips (1).

In order to condense the large amount of data so obtained, the average starch content of the sapwood has been calculated for each boring and is referred to as the 'starch index', but the limitations of such an average must be borne in mind, since the figures attributed to various grades of starch content bear no precise mathematical relation to one another. That is to say, grade 2 does not refer to an amount of starch twice that of grade 1, nor grade 6 three times the amount in grade 2. At the time of girdling in April 1937, all experimental trees had a starch index between 5 and 6, showing that starch was generally abundant throughout the sapwood (see Table II).

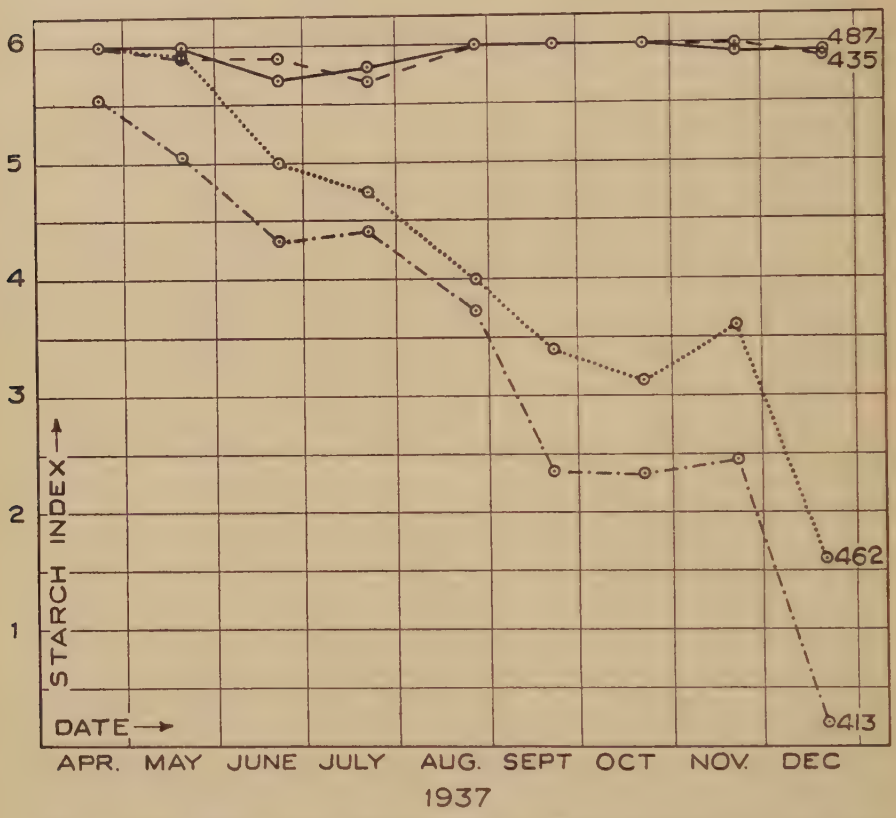

Fig. 1. Starch indexes of two girdled (413, 462) and two control trees (435, 487) plotted against time.

Borings were taken monthly at a height of 4–5 feet from two non-girdled trees, 435 and 487, and from two girdled trees, 413 and 462. The starch indexes are plotted against time in Fig. 1. Considering the limitations of the starch index figure and the difficulty of allowing for variations in starch distribution when sampling by means of increment borings, the curves show satisfactorily consistent trends. Apart from a very slight fall during June and July, the starch content of the sapwood at the bases of the non-girdled trees has remained steadily at, or very close to, the maximum. The curves for the

girdled trees, on the other hand, show a fairly regular decrease in starch content until September which, with the onset of colder weather, may mark the end of the true depletion period. The sudden fall in starch content occurring in December cannot at present be explained, although it indicates that the starch-containing cells in the trunk were still physiologically active. Since the corresponding drop in the curves of the control trees is extremely small, it is doubtful whether the fall represents a winter conversion of starch to sugar.

Borings were taken at a height of 4–5 feet from all trees on 21 December 1937. The trees were felled on 12 and 13 January 1938 and borings taken on the following day at points 2 feet below the girdle and midway between the girdle and ground-level. The starch indexes of the four control and twenty girdled trees at the beginning and end of the experiment are given in Table II.

TABLE II. *Starch indexes of trees at beginning and end of experiment*

Treatment.	*Tree No.*	*Starch index.* 22.iv.37. *A.**	21.xii.37. *A.**	14.i.38. *B.**	14.i.38. *C.**
Controls	435	6·00	5·89	..	..
	461	5·47	5·27	..	..
	487	6·00	5·93	..	6·00 (20 ft.)
	505	5·78	5·60	..	5·89 (20 ft.)
Girdled	413	5·55	0·20	0·00	1·20
	431	5·70	0·00	0·00	1·33
	433	5·67	2·00	1·50	3·40
	434	5·88	0·00	0·00	0·14
	437	5·91	2·00	0·33	1·88
	438	5·91	0·00	0·00	1·30
	453	5·92	0·90	1·00	2·88
	454	5·60	0·00	0·00	1·22
	455	5·00	1·00	1·60	3·08
	457	6·00	0·58	0·77	0·30
	462	6·00	1·60	0·15	0·36
	463	5·27	0·75	0·15	0·47
	468	5·90	3·83	4·00	4·78
	469	5·59	1·29	0·46	0·25
	481	5·92	1·38	0·00	2·70
	488	5·59	1·33	1·73	2·36
	498	5·57	2·73	1·31	1·90
	499	6·00	2·11	0·63	0·29
	502	5·55	0·00	0·00	0·00
	503	6·00	2·62	1·20	1·70

* *A.* Borings from 4 ft. above ground-level.
B. „ „ midway between ground and girdle.
C. „ „ 2 ft. below girdle.

The table shows that the control trees have approximately the same starch index at the end as at the start of the experiment, whereas there has been a considerable decrease in the starch content of the girdled trees. The starch indexes of borings from below the girdles of the twenty ringed trees show

considerable variation. There is a general tendency towards greatest depletion midway between ground and girdle and to least depletion in the region just below the girdle. Borings (taken 14.i.38) from 2 feet above the girdles of trees 413, 462, and 469 have starch indexes of 5·10, 5·85, and 4·43 respectively, indicating that the effect of the treatment has been confined to the sapwood below the girdle.

From numerous observations of the starch content of wood infested by *Lyctus* Powder-post beetles, it is thought that the minimum amount of starch required for development of the larvae corresponds approximately to grade 3, but at this level larval development is frequently abnormally prolonged. A sample, therefore, which has a starch index of 2 or less should be immune from *Lyctus* infestation, provided that any $\frac{1}{10}$-inch units assessed as grade 3 are isolated from one another and do not form a susceptible strip of tissue in an otherwise non-susceptible sample. Sapwood with a starch index between 2 and 3 will probably contain strips of susceptible wood, whilst samples with an index exceeding 3 must be considered liable to *Lyctus* attack. On this basis the girdled trees may be classified as follows:

Non-susceptible.	*Partially susceptible.*	*Susceptible.*
413	437	433
431	453	455
434	462	468
438	481	
454	488	
457	498	
463	499	
469	503	
502		

Of the twenty trees treated, the sapwood below the girdle of only nine is sufficiently depleted of starch, in the nine months during which they were left standing, to be regarded as immune from *Lyctus* damage. Eight trees have certain starchy areas which might make them liable to infestation, and three trees contain sufficient starch to render them definitely susceptible. The susceptible trees, 433, 455, and 468, are of relatively small girth and have 24, 20, and 26 annual rings per inch of sapwood respectively (see Table I) and may therefore be considered slow grown. The only other slow-grown girdled trees with more than 20 rings per inch, 453 and 503, also possess areas of high starch content.

CONCLUSIONS.

It has been shown that the process of girdling standing oak trees can be carried out conveniently and cheaply, the cost per cubic foot of timber below the girdle amounting to less than one penny. The excellent results obtained in the preliminary experiment at Robertsbridge, Sussex, have, however, not been confirmed by the present work; the reason for this is not clear. There is considerable variation in the rate of starch depletion between trees treated under the same conditions, which is possibly linked with variation in vitality.

There is also apparently a rather irregular variation in the rate of depletion of starch from different parts of the same tree. Under these circumstances, it would seem that the treatment cannot yet be relied upon for commercial production of starch-free, and, therefore, *Lyctus*-immune oak sapwood. A certain measure of success can be achieved, but further work must be carried out to determine the causes of the variation in starch depletion and to investigate the possibility of controlling them.

The Robertsbridge oaks may have produced seed during the experimental period, and thus had their rate of starch consumption accelerated; this factor was unfortunately not investigated. Few, if any, seeds were produced by the trees in Newland's Wood. Again, the date of girdling may have influenced the results, since there was 2½ months' difference between the starting times of the two experiments. Arrangements have been made to carry out a further experiment on twenty trees to determine whether girdling in July is more successful than girdling earlier, and to gain information upon other factors which may affect the rate of starch depletion, such as growth rate, crown size, seed production, &c.

ACKNOWLEDGEMENTS.

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I also take this opportunity to express my thanks to F. J. Potter, Esq., and D. Potter, Esq., of Messrs. Henry Brown & Son, Ltd., for their interest in the experiment and their willing co-operation.

SUMMARY.

Twenty standing oaks (*Quercus robur* L.) were girdled in May 1937 through bark, phloem, and cambium about 20 feet above ground, and were felled in January 1938. The treatment cost 0·73 pence per cubic foot of timber below the girdle, and this amount could without doubt be considerably reduced. Development of the current annual ring of wood was arrested, and the leaves fell a month earlier than normal. Depletion of starch from the sapwood, below the girdle, of all treated trees was recorded, but considerable variation occurred both between trees and in different parts of the same tree. Depletion commenced as soon as the trees were treated and probably finished about the end of September. A further reduction of starch content in December was recorded but the reason for this fall is obscure; it does indicate, however, that the starch-containing cells were still alive and functioning up to the time of felling. At the time of felling, three trees still contained sufficient starch to be adjudged definitely liable to *Lyctus* Powder-post beetle attack, nine were classed as non-susceptible, and eight as partially susceptible.

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PERMANENT SET OF TIMBER

BY R. A. G. KNIGHT AND R. J. NEWALL

(Forest Products Research Laboratory, Department of Scientific and Industrial Research)

INTRODUCTION.

WHEN dry timber absorbs moisture it expands, but upon re-drying through the same moisture range it contracts or shrinks to its original size. Under normal conditions the unrestrained movements of timber are reversible, and alternating exposure to a range of fixed air states will merely cause moisture and dimensional changes to repeat themselves at corresponding points of the cycle. There is no general tendency for the sizes to become progressively smaller or larger. Suppose, however, that the expansion consequent upon moisture absorption is not allowed to take place, as, for example, a panel that had originally been tightly fitted into a solidly made frame. After the wood has re-dried to its initial state it will be found to be smaller in width than formerly. This diminution has received the name of permanent set. From this description, which is the popular conception of the occurrence, it would seem that permanent set can be extremely troublesome in practice. Many possible cases will spring to mind, particularly where, as a precaution against possible shrinkage, timber has been over-dried prior to fabrication as panelling or flooring.

Actually, however, very little appears to be known about the quantitative aspect of permanent set, and whilst the theory of its formation lends itself readily to the explanation of numerous defects in manufactured woodwork, there are often simpler and less popular reasons for the apparent shrinkage of joinery. The obvious case of timber having been insufficiently seasoned for a particular purpose needs no mention, but that material dried to the correct average moisture-content should give trouble may appear inexplicable until the aspect of uniformity of moisture distribution across the section of the piece is considered in conjunction with the average figure. Again, even if the wood has been correctly dried at the factory, there is often no proof that it will be still in that state when fabricated. In short, it is difficult under practical conditions to attribute a particular defect to the effects of permanent set on account of other factors, any of which is as likely to have considerable influence on the case. On the other hand, a number of experiments conducted from time to time have definitely established that permanent set can indeed take place under conditions obtaining in practice, and that its effects merit serious consideration.

OUTLINE OF EXPERIMENTAL PROCEDURE.

Since no information on permanent set of timber was available, the experiments planned were necessarily of an exploratory nature. Briefly, the object

of the work was to compare by measurements of matched panels the effects of restraint imposed in various ways on the subsequent behaviour of the wood under different atmospheric conditions. Three standard air conditions were available, and the samples were transferred from one to the other to bring about the necessary moisture and dimensional changes. The Laboratory's three constant-humidity rooms running at 25° C. gave atmospheres of 30 per cent., 60 per cent., and 90 per cent. relative humidity, corresponding to moisture-contents in wood of approximately 7 per cent., 12 per cent., and 20 per cent. In addition, what was termed desiccation of the wood was obtained by the use of phosphorus pentoxide in closed vessels maintained at about 25° C.

The tests were conducted throughout on beech, the samples being carefully selected for straightness of grain. The boards were as nearly as possible quarter-sawn, tangential-sawn, or of composite grain, in which the growth rings made an angle of 45° with the faces. Prior to cutting into the test pieces, the boards or slats were planed to ¼-inch thick, approximately 5 inches wide by about 20 inches long, and were stored until uniform in moisture. From a slat three pieces were cut each 6 inches long, each of these being marked across the middle on both sides for measuring purposes, and the two outer samples were used as unrestrained controls or comparison boards. To the centre panel was applied the restraint by means of a special clamp according to the scheme of experiments (Plate III). The method of applying the clamps must be made clear. Suppose, for example, it was desired to suppress the expansion occurring between the conditions of 30 per cent. humidity and 90 per cent., i.e. whilst the sample was absorbing moisture from 7 per cent. to 20 per cent. The pieces would be stored in the 30 per cent. humidity room until repeated weighings showed no change. The clamp would then be applied and so adjusted that, whilst there was no slackness or space between wood and metal, the wood was not compressed in the slightest degree. The clamped piece and its attendant controls were then transferred to the 90 per cent. room and stored until the unclamped slats attained constant weight. It was then assumed that the restrained piece was also in the equilibrium state, but, as a precaution, the samples were always stored for another fortnight or so before unclamping. During the process of moisture-absorption by the samples, a close watch was kept on the clamp for spring, that is, for a separation of the clamping plates due to the forces exerted by the swelling wood. Most careful observations with a micrometer failed to detect any positive movement, however.

CONSIDERATIONS AFFECTING THE VALIDITY OF THE METHOD.

The validity of the experiment turns upon the truth of the assumption that the middle panel of the three would behave as the mean of the two outer pieces. In other words, the suppressed movement of the clamped sample must be the difference between its size and that of the free samples. Although the slats from which the groups of three samples were cut were most carefully selected for uniformity of grain, it was realized that complete concord of behaviour was unlikely to be realized, and it was for this reason that two

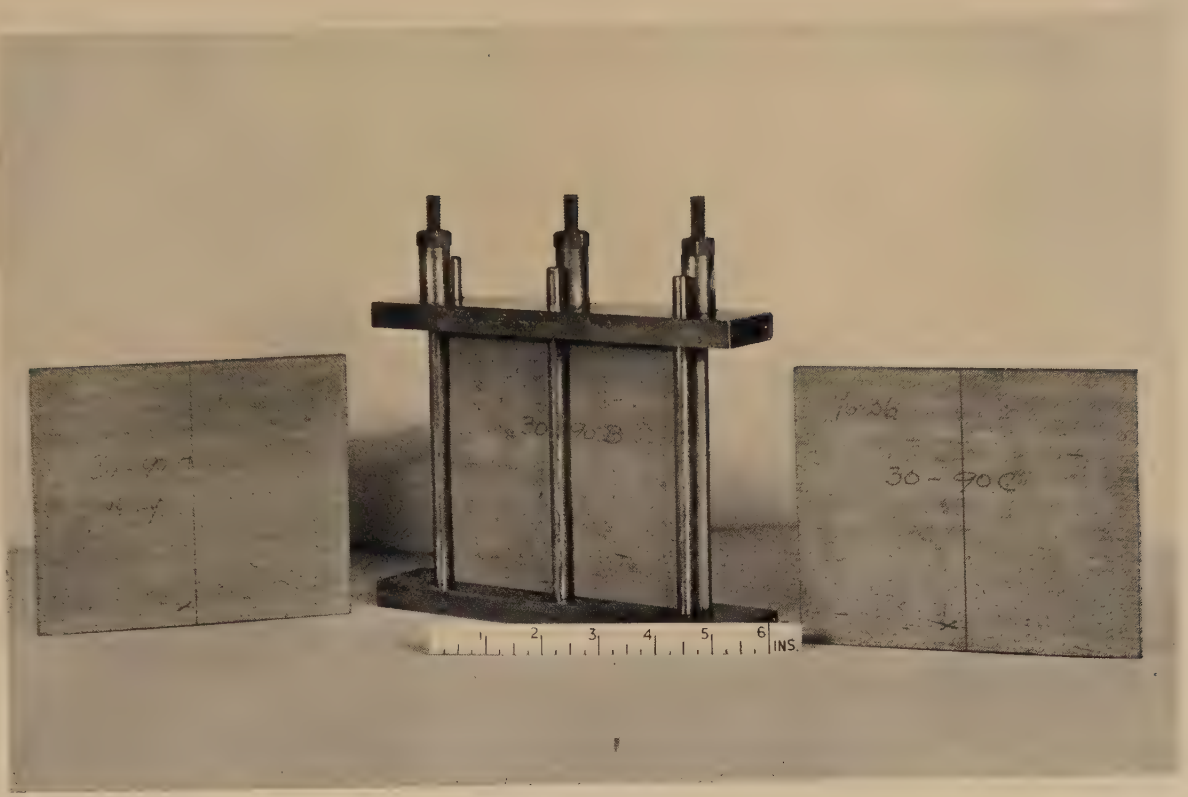

PLATE III

Trisected slat showing measuring lines and clamped centre-piece

unrestrained samples were employed, because it was considered that the average measurements on these two could with justice be used to ascertain the effects of restraint on the intermediate piece. As a check on this assumption, a group of samples was prepared and repeatedly subjected to the range of air conditions that would be employed in the main experiments, but all the three panels were free of restraint. Under the assumption made, the dimensional and other changes of the centre sample should have been the mean of those of the two outer pieces. As was anticipated, complete concord was not obtained, but the discrepancies that occurred were within the limits of accuracy and significance desired for the experiment. Under any particular exposure condition, the moisture-contents of the three panels agreed to within 0·1 per cent., a difference sufficiently small to be neglected. For convenience in analysis, the size of the panels at some prearranged condition was taken as 100, and upon this all movements were assessed. The figures for the two outer panels were averaged and compared with those of the centre piece. The maximum variation in size was $\pm$0·1 per cent, which was considered a satisfactory degree of concord.

It will be noticed in Table I that under the same storage conditions, but in different cycles, the moisture-contents vary somewhat. This in most cases is attributable to hysteresis[1] effects by which the moisture-content in equilibrium with a specific air state depends on the direction of approach to the steady state. Another contributory cause was the lack of completely constant control in the humidity rooms, which, at the time of these experiments, were still in a state of development. The significant point, however, is that the three samples in any one group all received identical treatment in each phase of the experiment, and the degree of comparison between individual pieces in a group may be viewed with confidence.

In the discussions that follow, it is convenient to refer to the humidity of the storage environment rather than to moisture-contents, but the actual values of the latter are shown in the tables and used in the analyses.

DESCRIPTION OF SERIES I TESTS.

The tests designated Series I were all carried out by a similar method, and it is sufficient to describe fully the procedure with one of the groups, and for this purpose the tests on composite-grain beech restrained over a humidity range of 0–90 per cent. have been selected. The observations are recorded in full in Table I.

The group of three samples was prepared as previously described, stored in a desiccator over P_2O_5, and maintained at 25° C. until repeated weighings and measurements showed the steady state to have been attained. The clamp was applied to the centre panel and all three transferred to the 90 per cent. humidity room. After the two control pieces had reached steady conditions, a further fortnight was allowed to elapse, and the clamp was then removed from the middle piece, which was at once weighed and measured. That the size of the clamped piece increased by 0·8 per cent. immediately after removal

Table I. *Beech—Composite grain*

Relative humidity.	*Humidity at which 'Set' occurred after conditioning at 0 per cent.*									*Humidity at which 'Set' occurred after conditioning at 30 per cent.*						*Humidity at which 'Set' occurred after conditioning at 60 per cent.*		
	30 *per cent.*			60 *per cent.*			90 *per cent.*			60 *per cent.*			90 *per cent.*			90 *per cent.*		
	Moisture content, per cent.	*Percentage of initial size.*		*Moisture content, per cent.*	*Percentage of initial size.*		*Moisture content, per cent.*	*Percentage of initial size.*		*Moisture content, per cent.*	*Percentage of initial size.*		*Moisture content, per cent.*	*Percentage of initial size.*		*Moisture content, per cent.*	*Percentage of initial size.*	
		Av. of free samples.	*Diff.*		*Av. of free samples.*	*Diff.*		*Av. of free samples.*	*Diff.*		*Av. of free samples.*	*Diff.*		*Av. of free samples.*	*Diff.*		*Av. of free samples.*	*Diff.*
Initial	0·9	100·0	..	0·7	100·0	..	1·1	100·0	..	5·9 M.D.	100·0	..	5·5 M.D.	100·0	..	12·2	100·0	..
	F. C.			F. C.			F. C.			F. C.			F. C.			F. C.		
Clamp removed	6·2 6·1	101·3	0·8	10·3 10·0	102·6	1·9	21·2 20·5	106·0	5·2	11·0 10·8	101·4	0·8	21·0 20·5	105·2	4·5	21·2 20·7	103·3	2·8
30%	6·2 6·3	101·5	0·3	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..
60%	10·0	102·7	0·2	10·5 10·4	102·8	1·2	..	..	..	10·9 10·6	101·3	0·5	..	..	..	..	..	..
90%	20·0	106·6	0·2	20·9	106·8	0·0	20·6 20·3	105·8	4·1	19·0	103·6	0·0	21·5 21·4	105·4	2·2	21·5 22·0	103·5	0·7
60%	12·5	104·0	0·2	12·0	103·8	0·2	12·7	103·4	3·7	12·2	101·9	0·1	12·1	102·5	2·2	12·4	100·5	0·9
30%	7·5	102·1	0·1	7·1	102·2	0·2	8·7 M.D.*	102·1	3·7	8·0 M.D.*	100·6	0·1	8·3 M.D.*	101·1	2·2	8·2 M.D.*	98·9	0·8
60%	10·4	103·1	0·2	10·4	103·2	0·2	10·9	102·8	3·6	11·5	101·5	0·1	10·5	101·8	2·2	10·8	99·7	0·8
90%	20·0	106·7	0·2	20·1	106·7	0·0	20·0	105·8	2·1	20·1	103·9	−0·1	19·4	104·7	1·3	19·8	103·0	0·5
60%	11·3	103·7	0·3	11·0	103·7	0·2	11·5	103·2	2·3	11·6	101·6	0·0	11·3	102·2	1·6	11·6	100·3	0·6
30%	..	..	..	6·4	102·1	0·2	6·8	101·6	2·4	7·0	100·4	0·1	6·7	100·5	1·7	6·7	98·5	0·7
60%	..	..	..	..	..	..	10·2	102·7	2·3	..	..	..	10·0	101·7	1·6	10·2	99·7	0·6
90%	..	..	..	..	..	..	19·1	105·6	1·8	..	..	..	19·1	104·9	1·2	19·4	103·1	0·6
60%	..	..	..	..	..	..	11·6	103·3	2·0	..	..	..	11·0	102·2	1·3	11·2	100·3	0·6
30%	..	..	..	..	..	..	7·3	101·9	2·1	..	..	..	7·0	100·9	1·5	7·1	98·9	0·7
60%	..	..	..	..	..	..	10·6	102·9	2·0	..	..	..	10·0	101·8	1·4	10·1	99·8	0·5
90%	..	..	..	..	..	..	18·9	105·6	1·6	..	..	..	..	..	..	..	..	..
Duration of test	13½ months			13 months			21 months			11 months			17 months			17 months		

* Denotes storage in Moisture-Content Determination Room, which was the driest environment available prior to the construction of the 30 per cent. Humidity Room.

of restraint indicated that the timber still retained its elastic properties to a small extent. The difference in size between free samples and that just out of the clamp (106–100·8 = 5·2) is termed the initial set. The three pieces remained in the 90 per cent. room until the middle piece attained constancy in size, for a slow creep took place after the release. The extent of this was about 1 per cent. above that of the elastic spring, making the final size of the centre sample 101·7 per cent. of its original size as against 105·8 per cent. for the controls. The difference, 4·1 per cent., was the final set. It will be noticed that one effect of clamping was to lower the equilibrium moisture-content by 0·7 per cent. This is of particular interest as being in agreement with Katz's thermodynamic equation for the swelling pressure of hygroscopic materials. The external pressure applied to the wood (in this case by its own suppressed swelling) has the effect of raising the vapour-pressure so that equilibrium with the former humidity can be attained only by the evaporation of moisture. The difference diminished after storage without the restraint in the 90 per cent. room subsequent to the removal of the clamp, and later it disappeared altogether. From the 90 per cent. compartment all three samples were moved from humidity room to humidity room in a drying and re-wetting sequence, and were allowed to attain the steady state in each. No further restraint was applied. The results show that the set remained constant during the 60–30–60-per cent. humidity treatment, but diminished with the restoration of 90 per cent. This second degree of set also remained until the next exposure to high humidity, and a third but smaller reduction took place at the end of the third cycle. At the end of 20 months, however, the initially restrained sample still remained about 1½ per cent. less in size than the free controls.

This is true in principle of all samples in which the set was induced by exposure to 90 per cent. air, and is shown graphically in Fig. 1, curve *A*, for tangential-grain beech restrained over 30–90 per cent. humidity. Where the set was caused by storage in a humidity lower than 90 per cent., exposure to the damper air practically relieved the set, or at least diminished it to negligibly small proportions, this being illustrated in Fig. 1, curve *B*, for tangential material restrained between humidities of 0 per cent. and 60 per cent.

The Series I tests were made on timber of three grain directions, but for brevity only the figures for the composite-grained samples are here recorded. The discussion that follows is, of course, based on the analysis of all available values. Swelling of the free samples was not linear with moisture-content,[2] but tended to be greater as the numerical value of the moisture-contents increased. Thus, on the basis of movement per 1 per cent. moisture-content, it was greater over the 60–90 per cent. step than over the 30–60 per cent. range, and greater also over the latter than over the 0–30 per cent. phase. Probably this was due to stresses induced in the timber consequent upon the comparatively sudden change of atmospheric environment. It would appear that the stresses diminish as the moisture-content rises. No simple relationship appears to exist between initial or final set and the swelling of free samples. Roughly, Initial set = ¾ Suppressed swelling, and Final set = ½ Suppressed

PERMANENT SET OF TIMBER
KEY
MOVEMENT OF FREE SAMPLE
MOVEMENT OF CLAMPED SAMPLE AFTER RELEASE
S SUPPRESSED SWELLING.
I INITIAL SET
SAMPLE IN CLAMP
R RESIDUAL SET
F FINAL SET
O.D. = OVEN DRY
SERIES I (CURVE B) BEECH TANGENTIAL GRAIN 0%-60% RANGE
SERIES III BEECH - COMPOSITE GRAIN (CURVE D) OVEN-DRY TO 90% OSCILLATIONS
UNRESTRAINED MOVEMENT
SERIES I (CURVE A) BEECH TANGENTIAL GRAIN 30%-90% RANGE
SERIES II BEECH - COMPOSITE GRAIN (CURVE C) 60%-90% RANGE
PERCENTAGE OF INITIAL SIZE
STORAGE CONDITIONS - RELATIVE HUMIDITY

FIG. 1.

swelling, and of the two relationships that of final set to swelling is the more stable. With groups of radial, composite, and tangential-grained samples, the ratio of initial set to swelling increases with the numerical value of the moisture-content, but at a faster rate than does swelling alone. This is most marked with the radial-grain groups, but in all of them sets produced by exposure to 90 per cent. air were disproportionately large. The ratios of final set to swelling tended the same way as those of initial set, but not in so marked a degree. It is perhaps surprising that a quarter of the suppressed movement should reveal itself as elastic deformation. Further discussion will be postponed until the results of Series II have been considered.

DESCRIPTION OF SERIES II TESTS.

The method of preparing, conditioning, and making observations on the samples in Series II was the same as in Series I, but the manner of treating the clamped piece was different. The clamps were not removed during the storage period in the humidity at which set was produced, and the sample, by storage in a drier atmosphere, was allowed to shrink naturally and so free itself from the clamp. The various groups were then moved from one humidity room to another, and, in general, were put through a cycle such that the highest humidity in it was lower than that at which set occurred.

The results are given in Table II. Analysis is complicated by the changes in moisture-content that occurred between the initiation of set and the first time that actual comparative measurements could be made. The ratios between the residual set when the sample was restored to its initial moisture-content and the total suppressed swelling vary between 0·55 and 0·75 (omitting the 30–60 per cent. results, which are unaccountably low). Unfortunately, a comprehensive comparison between Series I and Series II cannot be made on this basis, but such figures as are available show the residual set in Series II to be significantly greater. In general terms the set, during the exposure to humidities lower than that at which set was induced, tended to decrease slightly. Restoring the samples to the higher humidity caused the set to diminish appreciably, and to remain diminished when the next lower storage condition was again employed, as indicated graphically in Fig. 1, curve *C*. It is of interest that relations between the swelling and moisture-content of the free samples were much more nearly linear in this series, but it was again clear that the set produced increased with the numerical value of the humidity causing it, i.e. that produced over the range 30–90 was greater than that over 0–60 when expressed as residual set on return to original conditions over the moisture-content change-producing set.

Summarizing the results of Series II, it appears that the residual set produced by this method is greater than by that of Series I, possibly on account of eliminating the possibility of the creep recovery previously mentioned. It seems also that, once the clamped piece has shrunk clear, the set is more or less permanent unless the higher humidity is restored, and even then the reduction is less than in Series I.

Table II. *Series II: Beech—Composite*

Humidity at which 'Set' occurred after conditioning to 0 per cent.								*Humidity at which 'Set' occurred after conditioning to 30 per cent.*								*Humidity at which 'Set' occurred after conditioning to 60 per cent.*			
60 *per cent.*				90 *per cent.*				60 *per cent.*				90 *per cent.*				90 *per cent.*			
		Percentage of initial size.				*Percentage of initial size.*				*Percentage of initial size.*				*Percentage of initial size.*				*Percentage of initial size.*	
R.H.	*Moisture content, per cent.*	*Av. of free samples.*	*Diff.*	*R.H.*	*Moisture content, per cent.*	*Av. of free samples.*	*Diff.*	*R.H.*	*Moisture content, per cent.*	*Av. of free samples.*	*Diff.*	*R.H.*	*Moisture content, per cent.*	*Av. of free samples.*	*Diff.*	*R.H.*	*Moisture content, per cent.*	*Av. of free samples.*	*Diff.*
0	0·9	100·0	..	0	1·4	100·0	..	30	6·9	100·0	..	30	7·6	100·0	..	60	12·2	100·0	..
60	9·9	102·2	2·2	90	20·9	105·5	5·5	60	10·2	100·9	0·9	90	20·3	103·9	3·9	90	20·2	102·2	2·2
30	6·6	101·2	1·5	60	12·0	103·1	4·0	30	6·7	99·9	0·2	..	..	..	..	60	11·9	100·0	1·2
0	0·7	99·8	1·2	30	7·3	101·6	3·9	0	0·6	98·4	0·2	60	12·0	101·6	2·4	30	7·0	98·7	1·2
30	5·9	100·9	1·2	0	0·5	99·9	4·1	30	5·8	99·6	0·2	30	7·2	100·2	2·4	60	10·4	99·6	1·1
60	9·6	102·1	0·8	30	6·3	101·1	3·8	0	0·2	98·3	0·2	60	10·6	101·1	2·2	90	19·7	102·1	0·5
90	19·8	105·5	0·3	60	10·3	102·4	3·5	30	5·5	99·4	0·1	90	19·8	103·8	1·1	60	12·0	100·2	0·7
60	11·5	103·1	0·3	30	7·4	101·5	3·5	60	9·4	100·6	0·0	60	12·1	101·7	1·3	..	..	..	..
30	7·0	101·8	0·4	90	19·8	105·5	2·0	90	19·7	104·1	−0·1	..	..	..	..	..	..	..	..
..	..	..	..	60	12·2	103·3	2·2	60	11·7	101·9	0·0	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	30	6·6	100·4	0·1	..	..	..	..	..	..	..	..
Duration of test 13 months				14½ months				15 months				12 months				11 months			

DESCRIPTION OF SERIES III TESTS.

Series III comprised two special experiments intended to provide information on particular aspects of the occurrence of set.

Table III gives the results of the first of these. After conditioning a group of panels in 60 per cent. air, the clamp was applied to the middle piece, and all three transferred to 90 per cent. air until steady conditions obtained. Without touching the setting of the clamp (which was actually locked to prevent accidental alteration) the group was then moved back to the 60 per cent. room and the restrained sample allowed to shrink free of the clamp, just as in Series II. The next step was to restore the panels in the 90 per cent. room, the middle piece remaining in the clamp, this being still locked at its original size. Naturally the panel expanded and became tight in the clamp. This process was repeated several times and Table III shows that the effect was to increase the residual set slightly, from 1·2 to 1·7. It will be noticed that later in the test the free panels expanded rather more than initially, and presumably the clamped piece had similar tendencies. This alone would not account for the increase in set, for the additional expansion amounted to 0·2 per cent. only, and it has been shown that only about half the suppressed change remains as set. The lack of complete agreement in moisture-content equilibrium values was probably due to slight changes of conditions in the humidity rooms themselves.

TABLE III. *Series III: Beech (Composite Grain)*

	Relative sizes.		
Relative humidity.	*Average of free samples.*	*Difference of restrained sample.*	*Moisture-content.*
60	100·0	..	12·4
90	102·2	2·2	20·7
60	100·2	1·2	12·4
90	102·3	2·3	21·0
60	100·3	1·5	12·6
90	102·2	2·2	20·6
60	100·4	1·6	12·6
90	102·3	2·3	20·4
60	100·6	1·7	13·2
90	102·4	2·4	20·9
60	100·5	1·7	12·8
	Duration of Test 16 Months		

Some indication of the cumulative possibilities of set is shown in Fig. 1, curve *D*. A group of samples was oven-dried at 100° C., a clamp applied to the middle piece, and absorption permitted to take place in a 90 per cent. atmosphere. Oven-drying followed and the absorption process was repeated, the clamp being refitted closely to the middle piece whilst in the dry condition —the test thus differing in principle from that described above, the results of

which are given in Table III. As would be expected, the free samples steadily lost weight and size during the repeated dryings. Relative to the free samples the clamped piece exhibited considerable and ever-increasing set, having a diminution in width of over 20 per cent. when this part of the test was concluded. At this stage the samples were stored in the 90 per cent. room free of all restraint. The middle piece exhibited a slow creep, but finally settled to 14 per cent. less in size than its fellows. Upon oven-drying this figure remained unchanged.

RECAPITULATION.

The essential of the tests of Series I was that after steady conditions had obtained in the humidity causing the swelling, the restraint was removed and a further period of storage given. Upon removing restraint from the clamped piece, partial recovery occurred in two stages, namely (*a*) immediate or elastic spring, and (*b*) a slow creep to a size less than that of the unrestrained controls. The diminution after elastic spring occurred was termed Initial Set, and that remaining after prolonged storage was called Final Set. In round figures, Initial set = $\frac{3}{4}$ Suppressed swelling, and Final set = $\frac{1}{2}$ Suppressed swelling. In greater detail, set, swelling, and moisture-content did not exhibit linear relationships. The ratio of initial set to swelling increased as the absolute humidities became greater, i.e. the ratio was larger over 60–90 per cent. range than over 0–30 per cent. This was not so marked with the final set/swelling ratio. Free exposure of the deformed sample to humidities higher than that at which set was induced gave almost complete relief. Under the conditions of the experiment the maximum humidity available was 90 per cent., and samples set at this condition could not be given the aforementioned relief treatment, but re-exposure to this same humidity brought about progressive relief. Complete relief was never obtained within the time the experiment lasted.

Under Series II elastic spring and initial set could not be determined, and what has been termed Residual Set was measurable only after the return of the samples to the initial moisture-content states. This residual set, however, was in general greater than that produced in Series I. Further, from the limited data available, it does not appear that exposing the samples to humidity higher than that producing set will bring complete relief.

Series III demonstrated firstly that repeated swelling against a fixed restraint tends to increase the residual set. Again, it was shown that by the repeated application of complete restraint to a sample, the size can be progressively reduced by very considerable amounts. Further, whilst some relief can be obtained by high-humidity treatment, a large proportion of the set is of a permanent nature.

CONCLUSIONS.

From the viewpoint of conditions likely to occur in practice, Series II is the most illuminating, and this clearly shows that set, or diminution in size, can occur where absorption of moisture takes place under conditions of restrained

expansion. The experiment, in general, indicates that the amount of set can be appreciable and sufficient to spoil the appearance of fine wrought work. The adjective permanent is applicable only in a limited way and seems to depend on treatment subsequent to the occurrence of set. It is justifiable in some instances because a sample oven-dried and set by exposure to 90 per cent. air, and subsequently soaked in water, was found still to be smaller than its restraint-free fellow.

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NOTE ON SHIFTING CULTIVATION IN FINLAND (FROM INFORMATION SUPPLIED BY PROFESSOR HEIKINHEIMO)

BY W. A. ROBERTSON

A CENTURY ago Finland exported considerable quantities of rye which were grown under a system of shifting cultivation. Many of the practically pure pine areas occurring in the flatter lands at low elevations are due to natural regeneration of pine from adjoining belts on the abandonment of such cultivated lands.

Cultivation rotations fell as low as 20 years in the near neighbourhood of villages and have resulted in belts of pure grey alder, as under such a short rotation the pine had not time to reach seed-bearing age and the natural seed-trees were at too great a distance. Grey alder coppice was the only type of forest which could survive under such short rotations.

Rye was sown on the cut and burnt-over land in the autumn, the seed being covered by hoeing or ploughing. A plough with two almost vertical shares without coulter or mould board was used.

The system is being again experimented with as a possible means of ensuring pine regeneration in the moister localities which have been invaded by spruce, where the proportion of pine will decline progressively (Plate IV). In such cases natural regeneration of pine from adjoining forests will be insufficient and artificial sowing is adopted, the seed being sown in the month of May following the sowing of the rye.

PLATE IV

EXCURSION TO THE BORDER COUNTRY, 1938

BY W. H. GUILLEBAUD

THE proposed excursion to Ireland having had to be abandoned, the Society visited Liddesdale instead, the theme chosen for their tour being 'The afforestation of the White Lands'. On both sides of the border, the rolling Cheviot country stretches almost uninterruptedly for many a long mile; farms are few and far between and the roads narrow and winding. The tall moorland grass, *Molinia caerulea* or 'flying bent', with other and better pasture grasses, clothes the long gentle slopes, giving the hills a green aspect in summer but turning in winter to white as the bleached haulms of the bent wave in the wind. The rainfall of the south-west extremity of the Cheviots is relatively high, averaging about 50 inches per annum, while the intense glaciation of the soft rocks of the Carboniferous Sandstone series has covered the hills with a variable depth of Boulder Clay. The combination of high rainfall, relatively impervious soils, and gentle slopes results in surface conditions which can best be described as those of wet moorland. Apart from occasional steep slopes, and the relatively small areas where the underlying glacial drift is sandy and permeable, the higher land is covered with peat. The depth of peat is usually less than 1 foot except on flat or almost flat ridge tops, terraces, and hollows, where natural drainage is impeded. Owing to the high base-content of the drift, the peat is typically of an amorphous texture and is relatively rich in lime and other plant nutrients. Where drainage is badly impeded *Sphagnum* accumulates, with the formation of high moor, and *Molinia* gives place to Cotton grass, *Scirpus*, *Erica Tetralix*, and other typical bog plants.

The chief utilization of this type of land in the past has been sheep grazing, but its suitability for this purpose has been greatly reduced in recent years by a complex of sheep diseases, some of which at least appear to be associated with the wetness of the land. As a result, extensive areas have come on the market in recent years and have been acquired by the Forestry Commission for afforestation. That afforestation is technically possible is evidenced by the shelter belts, usually of mixtures of Scots pine, spruce, and larch, which are scattered up and down the Borders, but perhaps the outstanding evidence is provided by the pioneer plantation formed by the late Duke of Buccleuch at Moorburnhead.

The main object of the Society's visit was to see this plantation and also one of the new forests, Newcastleton Forest, established by the Forestry Commissioners on a similar type of land not far from Moorburnhead. The Society had the good fortune to be conducted over Moorburnhead plantation by Sir John Milne Home, Chief Factor to the Duke of Buccleuch, to whom the thanks of the Society are due for permission to visit the woodlands. Sir John also kindly supplied members of the excursion with a useful booklet of notes

on the history of the plantation. Moorburnhead plantation has an area of 502 acres and lies 4 miles to the south-south-east of the town of Newcastleton in Roxburghshire. The elevation ranges between 400 and 900 feet above sea-level, the general aspect is south-easterly, and slopes are moderate to very gentle. Planting started in 1913 and was completed in 1924. The principal species used was spruce, Norway spruce forming 47 per cent. and Sitka spruce 41 per cent. of the crop; the remainder consists of Japanese larch and Douglas fir with a few other miscellaneous species. Those responsible for the formation of this plantation are to be congratulated on their wisdom in selecting spruces for their main species. In the light of our greater knowledge of to-day it is quite clear that this was the best possible choice. The plantation was formed for the most part by notching transplants direct into the soil, in other words no screefing or removal of the vegetation was done. The method of turf planting, introduced into Scotland some years previously by Sir John Stirling Maxwell at Corrour, was tried on a small scale at Moorburnhead, but unfortunately not on the typical white land. The area selected for turf planting, was a *Calluna-Scirpus* bog near the top of the plantation, and the failure of the plants to grow on what we now know to be an extremely poor type of peat prevented any further trial of the method in subsequent years. Before planting the area was enclosed against sheep but not against rabbits, these vermin having been virtually exterminated as a result of a prolonged and well-conducted campaign on the part of the estate staff. Surface drains were run through the wetter areas, but although the drainage was probably fairly intensive according to the standard of the time, considerable additional drainage became necessary. One result of keeping out the sheep and of the new drains was to encourage the growth of *Molinia* and other grasses, and the young trees had a very severe struggle against the vegetation. They held their own, however, remarkably well, and though there were many losses these were replaced, and in the older blocks canopy has almost everywhere been established.

In the oldest blocks, now 24 and 25 years old, the spruce were planted at about 4 feet apart, here and there rather closer, but in the later planting the distance was extended to 4½ and 5 feet.

Growth of the spruces in the early years was very closely linked up with the vegetation types. On flush ground, i.e. where there was a constant downhill movement of water through the surface-layer of the soil, neither of the spruces checked appreciably, and after 7 or 8 years these flush patches revealed themselves all over the area by the sturdy growth of the trees. Much the same applies to a stretch of peat-free land covered with *Deschampsia caespitosa* in the lower part of the plantation, but on the *Molinia*-dominant types, and more especially where a *Molinia-Eriophorum vaginatum* type occurred, the spruces checked for many years before getting away. Evidence from the Commission's more recent plantations at Newcastleton and elsewhere in the Border suggests that by turf planting most of this check can be avoided. In general, Sitka spruce has grown more rapidly than Norway spruce at Moorburnhead, and the difference is most marked on the poorest ground. The impression left by the

plantations at the moment is that Norway spruce is a satisfactory species on all the better ground, e.g. the pure *Molinia*, *Molinia*-grasses, and *Deschampsia caespitosa* types, while the *Molinia-Eriophorum*, and still more the *Erica Tetralix-Scirpus* types are better under Sitka spruce. There is little to be said about the other species planted on the area; neither Japanese larch nor Douglas fir has proved a success, and much of the land planted at one time with these species has had to be replanted with Sitka spruce.

Thinning is about to commence in the older spruce blocks, mainly in the Sitka spruce areas, the bulk of the Norway spruce being still on the small side for a thinning. The Society visited some of the stands in question and a discussion arose as to the type of thinning which should be carried out. An ordinary low thinning would remove a considerable number of semi-suppressed and suppressed stems, few of which would be large enough for sale as pit-props; on the other hand, a light crown thinning would enable some of the groups of dominants to be broken up, and although fewer stems would be cut most of the material would be saleable. The estate propose to lay down a tramway to get the thinnings out to the main road.

When the plantation is regarded as a whole, it represents a very successful pioneer effort at afforestation. A complete crop of spruce has been established over practically the whole of the area, and as Sir John Milne Home pointed out at the start of the excursion, a tract of land which under sheep grazing barely afforded the half-time employment of one shepherd now employs at least seven times as much labour and gives every promise of being a profitable undertaking financially.

Besides visiting Moorburnhead Plantation the Society also spent a short time in an older wood known as Harelawpike about one mile distant from Moorburnhead. This wood is 180 acres in area and 60 years of age. The species consist of a mixture of Norway spruce, Scots pine, and European larch in about equal proportions, with a few hardwoods such as oak, ash, birch, beech, and alder. The outstanding feature of the wood is the way the spruce has dominated the other species, especially on the wetter patches of ground. It was probably the evidence of this plantation that largely determined the choice of the spruces as the major species for planting at Moorburnhead.

The other forest area visited by the Society was Newcastleton Forest. To quote from the notes kindly provided by the Divisional Officer, Mr. A. H. Gosling: 'The forest lies in Liddesdale in Roxburghshire, and on its south-east side marches with Kershope Forest in England where topographical and soil conditions are very similar. Newcastleton is one of the earliest Forestry Commission areas in Scotland, having been acquired in 1920. Afforestation began in 1921 and has continued each year until now, at the close of the 1937/38 planting season, 2,366 acres have been planted and there are still 536 acres remaining to plant.' Topographical and soil conditions closely resemble those at Moorburnhead, the chief distinction being the greater range of elevation at Newcastleton (from 500 to 1,300 feet above sea-level), and the occurrence of considerable areas of basin peat. *Molinia* is the dominant grass, as at Moor-

burnhead, and the same series of *Molinia* types occur which change to a *Deschampsia caespitosa* type on the wet but peat-free slopes and to *Erica Tetralix-Eriophorum-Scirpus-Calluna* on the peat bogs. Basalt dykes outcrop in places over the forest, and here a bracken-*Nardus-Anthoxanthum* community forms a welcome change to the monotony of the *Molinia* types.

The wet moorland conditions leave little scope for choice of species, the area is typically suitable for spruce, and the only question as a rule is the choice of the European or the north-west American species. In the early years the mistake was made of planting Sitka spruce in hollows on the low ground, with the consequence that a great deal of frost damage has resulted. Now the general rule is to use Norway spruce at the lower elevations and on the better types of peat, and to restrict the use of Sitka to the higher ground, avoiding frost hollows where these can be recognized. Other species tried at Newcastleton include Japanese larch, which succeeds quite well on the bracken slopes, and Scots pine, which, however, does not thrive. *Pinus contorta* is now being planted to some extent on the tougher ericaceous peat, but is badly crippled by blackgame during the first few years.

During the first 5 or 6 years work the plants were notched into the peat after removing the surface herbage (with a mattock). The results were not satisfactory, the plants checked badly except in the *Juncus* flushes, and losses were considerable. With the gradual introduction of turf planting a great change came over the appearance of the forest, failures diminished remarkably, and except in the basin peat bogs the initial check, which was such a feature of the earlier plantations, virtually disappeared. The technique of turf draining has been brought to a high pitch of efficiency at Newcastleton, and a demonstration was staged for the benefit of the Society. Newcastleton drainers work singly, the man first cutting the line of the drain on one side, using a rutting spade and working uphill, and then working downhill to cut the other side. When back at the foot of the slope he starts to cross-cut the drain turfs, at the same time jerking each turf half out with a deft movement of the spade. The cross-cutting completed, a drain hook (or hack) is used to distribute the turfs, herbage side down, on either side of the ditch and at the required spacing. Finally a shovel is used to bottom the drain. The piece-work rate for cutting the drain and laying out the turfs is only 1*s*. per chain over the greater part of the forest. On Norway spruce sites, the drains are laid out 6 yards apart and the turfs spaced at 5 feet by 5 feet, costing 36*s*. per acre. With Sitka spruce, the turf spacing is usually 5½ feet by 5½ feet, requiring a distance of 7 yards between drains, and the cost reduces to 32*s*. per acre. The exceptionally low piece-work rate of 1*s*. per chain is partly due to the relatively easy conditions as regards depth and consistency of the peat, but partly also to efficient labour and good supervision. Among other advantages of turf planting on the 'White Lands', one that deserves to be stressed is the reduction in the subsequent cost of weeding; whereas in the case of direct planting an expenditure of 30*s*. to 40*s*. per acre will usually have to be incurred on weeding during the first 3 years, more than half of this cost is saved by turf planting. Apart from the raised

position of the plant, turf weeding is much easier than the weeding of flat planting because the drains at once indicate the direction of the rows.

Among other interesting points noted in the course of the excursion were firstly the fairly rapid response of the smaller basin peat bogs to drainage, one such area had a vegetation composed mainly of *Scirpus*, *Eriophorum vaginatum*, *Erica Tetralix*, *Calluna*, and *Vaccinium*. Drains were put in in 1934 and already a very marked change has set in, *Scirpus* has greatly diminished and *Eriophorum vaginatum*, *Aira flexuosa*, and bilberry are now much more prominent. The sphagnum moss layer has given way to hypnoid mosses, and conditions now appear favourable for the turf planting of Sitka spruce. A second point of interest was a 1920 plantation of Japanese larch, near the foot of a long slope, which had been badly damaged by frost shortly after planting. The gaps so caused were filled up in 1927 with Sitka spruce, but many more spruce were planted than were actually required to complete the stocking, and recently the larch, which were rough and poorly shaped trees, were drastically thinned to allow the spruce to get through into the canopy. These spruce which have grown up under the partial shade of the larch are notably cleaner grown and straighter than the trees in an older plantation of Sitka spruce higher up the same slope. The latter plantation was formed in 1920 by notching into the natural surface of the peat at a spacing of $5\frac{1}{2}$ to 6 feet, the trees made the irregular development usual under these conditions and though now in canopy were very rough and heavily branched. There can be no doubt that the Sitka spruce grown under the partial shade of the larch will produce timber of a better quality than that from the pure plantation above.

There remains for mention a short visit paid under the guidance of the Divisional Officer, Mr. A. H. H. Ross, to the Forestry Commission nursery of Kershope, on the English side of the Border. The standard method of sowing here is the drill, and there was a short discussion on the pros and cons of drill sowing as compared with broadcast sowing. Broadcast sowing is quicker, the distribution of the plants usually more uniform, and it is easier to lift the larger seedlings if these are required for lining out to produce 1-year–1-year transplants. On the other hand drill sowings are cheaper to weed, easier to protect against frost-lift, and the cultivation between the drills is probably beneficial. The Research Branch of the Forestry Commission is carrying out an investigation at the present time on this problem.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION, CAMBRIDGE, 1938

SIR ROY ROBINSON was Chairman of the Sub-section and Mr. Thomas Thomson was again Secretary. Mr. C. H. Thompson was Local Secretary and he arranged an excellent series of excursions in Cambridgeshire and Norfolk.

The following is a list of the papers read:

Sir Roy Robinson: 'The Home-grown Timber Supply.'

Symposium on 'The Cultivation of British Hardwoods'.

Mr. D. W. Young: 'The Position of Hardwoods in British Forestry.'

Mr. A. P. Long: 'The Oak.'

Mr. A. L. Felton: 'The Beech.'

Mr. J. Macdonald: 'Ash and Sycamore.'

Mr. A. H. Popert: 'Alder and Birch.'

Mr. W. H. Guillebaud: 'Progress of Experimental Work on Hardwoods.'

Joint Discussion with Section K (Botany) on the 'Ecological Aspects of Afforestation'.

Dr. A. S. Watt: 'The Significance of Breckland in British Forestry.'

Professor H. M. Steven: 'The Ecological Aspects of Afforestation in the Hill Country.'

Mr. R. Ross: 'The Colonization of Abandoned Agricultural Land in South-west Cambridgeshire.'

Professor W. Neilson Jones and Mr. A. G. Morton: 'Some Features of Soil and Growth on the Wareham Heaths.'

Mr. C. H. Thompson: 'The Present Position of Forestry at Cambridge University.'

Mr. G. Metcalfe: 'The Morbid Histology of Watermarked Willows.'

REVIEWS

Forestry and State Control. By R. S. Troup. Clarendon Press, Oxford, 1938. Price 3*s*. 6*d*.

Review by the Editor

THERE are few, if any, well-informed persons who do not admit that the state of private forestry as a whole in this country leaves much to be desired. Alike on grounds of defence and the proper utilization of our resources, the condition of many private woodlands cannot be allowed to deteriorate indefinitely. The question is, How can an improvement be best secured? This subject has been discussed privately and publicly for several years, but a sound and agreed solution is not likely to be reached until both those immediately concerned, and the public as a whole, have available to them a clear statement of the position in this country, and also information on how other countries have tackled the same problem. It faced other countries earlier and more acutely than it has this country, and there is experience, extending over almost a century in some countries, of measures taken to maintain private forestry.

It was a necessary step in formulating public opinion that this experience should be made readily available. No one so well qualified to do so as Professor Troup could have been found, because he has been in intimate touch for twenty years with most of those countries which have longest experience with different methods of control. Moreover, he has the gift of simple, clear, and concise exposition, as well as unrivalled knowledge of forestry in all parts of the world. This small book of 83 pages should, therefore, be read not only by all landowners, agents, and foresters, but be brought to the notice of as large a circle of the general public as possible.

The book is divided into two parts. In the first part there is a general discussion of private forestry in its setting of forestry as a whole, and in the second part is set out the measures of assistance and control which operate in ten European countries selected to give a wide range of examples.

It is shown that this country has not only the smallest percentage of forest of any country in Europe, but the largest percentage in private hands. Even with the steady increase in state planting, this is likely to be so for some considerable time. While not taking an alarmist view of a timber famine, the available data show that the long-term trend will be towards decreasing world supplies and rising prices. This will inevitably affect countries such as ours, dependent mainly on importation. Then follows a discussion of the reasons which have led to state control, and the different measures that can be applied. While state-owned forests are a necessity, Professor Troup rightly considers that private forestry has a definite and useful function to play. The problem is, therefore, the improvement and not the elimination of private forestry. The position in this country is then considered at some length, and the effect of the different measures of assistance already given discussed. While the author considers that the system of planting grants has been useful to those interested, it has not proved an incentive to those unable or unwilling to plant, while it has not improved silviculture and management as a whole on private estates. He advocates the employment of properly trained forest managers, grouping the smaller estates under one man where necessary, with liaison with the state department. Some legal enforcement of good management may prove necessary, and it is to guide opinion on this controversial matter that the

measures of assistance and control taken in Austria, Czechoslovakia, Denmark, Finland, France, Germany, Italy, Norway, Sweden, and Switzerland are given.

One subject that many owners consider vital is not discussed, namely measures designed to secure a more reasonable level of prices, particularly for products, such as pitwood, from thinnings. This is of special importance in regions distant from consuming centres.

The author is to be heartily congratulated on this book which cannot but have an important influence on forestry in this country. The Clarendon Press have provided an attractive format.

Forest Pathology. By J. S. Boyce. McGraw-Hill Publishing Company Ltd., London, 1938. Price 30*s*.

Review by W. R. Day

THE main purpose of this book is to present a concise review of the diseases of forest trees, and especially those with which fungi are associated. The book has been written for the student of forestry, and as a reference book for the practising forester. Because of this the diseases described are grouped according to the type and part of the tree affected, and not in accordance with the taxonomic grouping of the pathogens concerned. The taxonomic position of the fungi or other pathogens is, however, indicated in the text.

There are twenty-one chapters in the book, of which sixteen are concerned with diseases caused by parasites, and with the decay and staining of timber. One chapter is devoted to non-infectious diseases. There are three introductory chapters, of which two deal with general matters, while the third gives a short review of the morphology and classification of the fungi. The final chapter is concerned with principles of the control of forest diseases. There is a short appendix on fungicides, and a longer one which gives the scientific equivalents of the common names of plants used in the text. Adequate literature references are given at the end of each chapter. The book is well got up and printed, and the illustrations are good.

This is a book which may be recommended to any who are interested in forest pathology. It is, naturally, written for the North American forester, and greatest attention is paid to diseases of present importance in that continent, such as the chestnut blight caused by *Endothia parasitica* and the White pine blister rust caused by *Cronartium ribicola*. The important forest parasites in Europe are mentioned, but they do not necessarily receive much attention, while many of the less important ones find no mention at all. There is no book, at the present time, which deals so adequately with forest pathology from the European standpoint, as this does from the North American. It is much to be desired that one should be produced.

Dr. Boyce is to be congratulated on his careful and authoritative work. It will give valuable service in the cause of forest pathology.

Wird die Zuwachsleistung der grünen Douglasie durch Grünästung nachweisbar beeinflusst? By W. Weck. *Forstarchiv*, vol. xiv, no. 17, 1 September 1938.

Review by W. H. Guillebaud

THE problem discussed in this short article is whether, or more accurately to what extent, the growth increment of the Coastal form of Douglas fir is affected by live pruning. The answer given is based on the examination of three Douglas fir stands, aged respectively 22, 26, and 52 years, which were pruned with varying degrees of

severity in the Forest of Eberswalde in the early spring of 1936. Scattered trees only were pruned, so that unpruned trees of approximately the same diameter and height were available for comparison. Some of the pruning was almost incredibly drastic, e.g. trees over 80 feet in height were left with only 9 feet (three whorls) of live crown. The effect on the increment was studied by taking out two cores from each tree with a Pressler borer, one from the south and the other from the east side of the tree at breast height.

From each stem the average annual basal area increment for the years 1931 to 1935 was determined and related to the mean basal area increment for the years 1936/7 following the pruning. The method is an interesting one and should, given an adequate number of trees, yield a reliable result.

Weck, most commendably, publishes the whole of his data, and arrives at the general conclusion that Douglas fir is extraordinarily tolerant of very drastic pruning; of those trees pruned to the top three whorls of branches very few died or appeared in any way sickly; the increment is certainly affected by severe pruning, but as long as the pruning does not remove more than one-third of the living crown and leaves 40 per cent. of the stem-length under foliage, there is little if any reduction in increment in the two years subsequent to the pruning.

This latter conclusion may be correct, but the Reviewer would feel more confidence if the writer had tested a larger number of trees. It is to be feared that the comparisons would not bear statistical analysis, and we venture to suggest to Herr Weck that he should confirm his conclusions by repeating this interesting investigation on a somewhat larger scale and applying statistical analysis to the data collected.

Die Ergebnisse zweier Lärchenherkunftsversuche im Tharandter Wald. By Prof. Dr. K. Rubner. *Tharandter Forstliches Jahrbuch*, vol. 89, Part 7, 1938, pp. 465–91.

Review by T. Thomson

In view of the great importance of the question of local races of the larch, the author obtained samples of seed from a number of different sources, and sowed them in a nursery in the Tharandt Forest in spring 1930 and 1931 in order to raise them in experimental plots. The samples were 21 in number, and in the majority of cases the fact that the mother trees were truly indigenous was well established. Details of the place of origin, including elevation, age of mother trees, &c., are given, but to reproduce them would take too much space. It is, however, possible to group the various samples because the subsequent behaviour of the trees showed, at any rate, some indication that there was a similarity in the characteristics of the plants from certain regions. These regions are: Sudeten, Poland, High Alps, Middle Alps, Vienna Forest, High Tatra (Czechoslovakia), and Scotland. The Sudeten region is represented by two samples from Jägerndorf and Reinerz respectively. The former is on the lower slopes of the Sudeten range at an elevation of 500–600 m. (1,600–1,750 ft.), whilst the Reinerz sample was from a somewhat lower elevation, and the mother trees, though not native to the site, were undoubtedly of local origin. The one sample from Poland was from a single tree, 250 years old, growing at an elevation of 200 m. Two samples were from the High Alps (Briançon and Pontresina), both from elevations of 1,850–2,000 m. Ten were from various sources in the Alps from 900 to 1,700 m., two from Vienna Forest, 350–400 m. and 740 m. respectively, and three from High Tatra (900, 1,300, and 1,450 m.). The sample from Scotland is stated to be from 'Abovayshire' (possibly a mistake for Moray-

shire), where the larch is, of course, not indigenous, and may have come from several original sources.

The experimental seedlings were planted in two areas, referred to as Nos. I and II, in the Tharandt Forest. Area No. I lies at an elevation of 375 m. (1,230 ft.) and has a heavy clay soil, especially in the somewhat lower eastern end, whilst the western, some 1–2 m. higher, has a more favourable loam soil. Though the ground, after the clearing of the previous crop of spruce, showed at first no variation in character, after one year the eastern third of the area became wet and overrun with such a thick matting of rushes that a drainage ditch had to be made. These marked local variations in the soil of the area would have, however, no perceptible influence on the growth of the larch, which, according to the author's long-continued observations, is extraordinarily indifferent, at least in the first 8–10 years, to the nature of the soil. It grows with remarkable uniformity on soils of the most varied character, and only fails to flourish in youth on dry and sterile sands.

Unfortunately various plots suffered in different degrees from Pine Weevil and mice, followed by drought which necessitated the beating up of certain of them, and as some of the plots were planted a year later than others, competition with weeds was more severe in their case than with those first planted. The beating up, which in some cases had to be done with younger plants, and the effects of weed competition, made it advisable to reduce the effective age of certain plots in comparison with others by one year. In Area No. I the plots were arranged in two rows running east and west, with a row of comparison plots between them. The Jägernsdorf (Sudeten) strain was selected as the standard of comparison: nine plots of this were planted in a strip, each having a plot of another strain to the north and another to the south of it.

Besides the damage referred to above, a severe late frost on 8 May 1935 affected all the plots as shown by the browning of needles on the dwarf shoots, but by far most severely the somewhat lower lying plots 'Briançon' and Gschnitztal (1,700 m.). It was later evident, however, that the somewhat lower position of the plots in question was not the cause of the more severe damage, but that it was due to the greater sensitiveness of the races themselves. The adjoining plot of Sudeten larch was practically uninjured. All the lots browned by the frost, with the exception of 'Briançon', had fully recovered after a year and were none the worse, with the possible exception of Gschnitztal and Pontresina (2,000 m.). Compared with the damage to the Briançon plants, the injury was slight. Any doubt as to the correctness of this observation was removed by another frost at the end of April 1938, through which the Briançon plants suffered badly, the Gschnitztal and Pontresina plants less, but still noticeably, the remaining Alpine lots only slightly, whilst the rest, especially the Jägernsdorf lot which was least advanced in leafing, were hardly affected at all.

In order to meet the objections that the plots might not be fully comparable, owing to the incidence of these various misfortunes, a second set of experimental plots was established in Area II, which developed without serious injury and under more favourable conditions. This area lies on a north-east slope at 370 m. elevation. The soil conditions appear to be quite uniform, and beating up was necessary to a much less extent; curiously enough, the Sudeten larch, which had been one of the least troubled in Area I, required most attention in this case. Planting was done in autumn 1932. Unfortunately the supply of planting-material was not sufficient to allow of all the lots used in Area I to be included. Only the Alpine lots (except Gschnitztal and Briançon), the Jägerndorf and Scottish strains were planted again, together with a sample of Swiss trade seed from low elevations in the Swiss Alps and lots from Kalkögel (1,400 and

1,000 m.) which had not been included in the previous experiment. The Jägerndorf plants were again used as a comparison. The area is triangular in shape, so that the arrangement of the plots could not be the same as in the previous experiment. The Sudeten plants were used in three long plots running vertically to the longest side of the triangle, so that each adjoined three or four plots of the other strains of plants.

Owing to the rapid growth of the larch it was desirable to begin making height measurements early. Even at 6 years of age a number of the trees were partially suppressed, so that it was decided to measure the height only of the 50 per cent. highest stems. Owing to differences in the age of the plots in Area I the measurement at the end of the growing-season in autumn 1936 of the older plots included besides the total height also the length of the annual shoot. The younger plots were measured in the autumn of 1937 and the year's growth also recorded. In Area II the heights at the end of the growing season of both 1936 and 1937 were measured.

The average heights and annual shoot lengths are set out in tables in such a way as to enable a comparison to be made of the height growth at 6 years, and in certain cases 7 years. The following is a brief summary of the conclusions reached:

1. The fastest-growing strain in youth is the Sudeten larch. It reached with 6 years unchecked growth on the average 3·00 to 3·50 m. and more, with 7 years 4·00 m. and more. The average length of leader at this age was 0·60–0·80 m. and over.

2. Almost equally fast is the Vienna Forest larch, reaching 3·00 m. at 6 years and nearly 4·00 m. at 7 years with a leader of nearly 1 m. on the average.

3. The Tatra larch is only slightly behind the last mentioned. There was no difference in the height growth of the lots from the three elevations 900, 1,300, and 1,450 m.

4. The Alpine lots from middle elevations (900–1,700 m.) reached 2·10–2·60 m. at 6 years of age, only exceptionally somewhat more. There was no significant difference in height growth of the various lots from different elevations within the limits given above.

5. The High Alpine plants (Pontresina and Briançon) (1,800–2,000 m.) remained decidedly behind the above in height growth, and reached only 1·75 and 2·20 m. at 6 years and 7 years respectively. Leaders averaged 0·35–0·40 m.

6. The Scottish larches were about 2·80 m. high at 6 years and 3·25 m. at 7 years. They grew faster than those from the middle Alps but more slowly than the Sudeten, Vienna Forest, and Tatra larches.

8. All the samples appear more or less sensitive to the troubles of youth. So far there is no difference with regard to bending of the stems by wind and snow, though the faster-growing lots are perhaps more sensitive. Against spring frosts the high Alpine lots are most sensitive, the Sudeten larches the least, though the other lots were not permanently damaged by late frost. This applies especially to the Vienna Forest, Tatra, and Polish larches. Larch canker has not been found so far on any plot. The Larch Mining Moth appears not to spare any of the strains.

9. The occurrence of blue-green needled individuals in many of the plots could not be brought into any relation with the elevation of the original site, nor was it associated with differences in rate of growth of the individual plants.

10. The duration of growth in height was found to be greater in the fast-growing strains (Sudeten, Vienna Forest, Tatra) in which cases it extended until the end of September or beginning of October. This indicates that these strains are not suitable for sites subject of early frosts or high mountain regions. No damage by early frosts was observed in the experimental areas.

The article is illustrated by a number of photographs which bring out the

differences in growth between the various plots more clearly than the figures given in the text.

The experiments are, of course, only in the initial stages. So far, information is practically confined to height growth in the earliest years and sensitiveness to late frosts. It is in the later stages that the important differences between the various strains may be expected to show themselves. Susceptibility to canker, stem form, branchiness, shade tolerance, and course of height growth in later years are among the characteristics which may be proved to differ in different races. It is by no means certain that the race which proves ultimately to be best in one locality will also be the most suitable in another. British conditions may call for the employment of a different race of larch from that which is found ultimately to be most suitable for the Tharandt Forest. Nevertheless, one may expect valuable guidance from experiments such as these, which will at any rate show if there are differences in essential characteristics between races of larch. These experiments will also serve as a comparison with similar Forestry Commission experiments now in progress in this country. It would also be useful to collect as much information as possible about the provenience of the plants used in forming larch plantations which are now growing in this country and have shown clearly whether they are of a good type or not. Unfortunately, information on this point is seldom available, especially in the case of older woods, which often appear much finer than the younger ones promise to be. The superiority of the original Scottish strain over most of the others introduced subsequently is probably due to its having been brought from some region other than the Tyrol and the Swiss Alps, from which the bulk of the trade seed has been coming for many decades. It has been suggested that it is a Sudeten strain, but it is impossible to prove or disprove this now. It was certainly introduced before larch seed was a regular article of commerce.

It remains to be seen whether the layout of the plots will enable site variations to be assessed. It would appear that an arrangement in a Latin Square or Randomized Blocks would have been better. This experiment should, however, make a contribution to this important but difficult subject.

NOTICES

Plant-Growth Substances. By Hugh Nicol, Ph.D., F.I.C. Leonard Hill, London, Pp. xii+108. Illustrated. 1938. Price 3*s*. 6*d*. net.

IN this book Dr. Nicol has brought together for the first time a considerable amount of hitherto scattered information on indole compounds and other chemical substances which exert a growth-regulating effect on plants. Indole-acetic acid, for example, has been found to induce root growth when it is painted on the stems of plants, and is now commonly used for accelerating the rooting of plant cuttings. The practical significance of these effects is reflected in the marketing of artificial growth-regulating substances and in the increasing attention given to the subject by both laymen and scientists during the last few years.

The first two chapters are intended for the layman, and they outline the story of the discovery of growth substances and give instructions for using the commoner ones for striking plant cuttings. The chapters which follow deal with the chemistry of typical groups of growth substances, the results of scientific tests on root initiation with them, and their occurrence in natural products such as urine, decaying vegetation, &c. A particularly interesting chapter is devoted to the chemistry of urine, which contains several plant-growth substances, whilst another deals with the problem of the concentration of growth substances in relation to toxic effect on plants. Finally, the classification and nomenclature of these substances are discussed and an account is given of chemical and plant-physiological tests for them. The reader desirous of studying the literature of the subject will find a great deal of helpful direction in the lists of books and journal references.

Eighteenth Annual Report of the Forestry Commissioners. H.M. Stationery Office, London. Price 1*s*.

THE Report opens with an account of the progress made in the Special Areas. Five hundred and sixty-eight thousand acres were examined in the Northern and South Wales areas, of which 152,000 acres were found to be subject to common rights and not available. Owners of about 27 per cent. of the balance were ready to negotiate, and during the year 42,900 acres had been passed for acquisition. In the Special Areas 3,000 acres were planted, and 14 million seedlings lined out, and 2,000 lb. of seed sown to provide stocks for future planting.

The total area acquired now reaches 1,005,500 acres divided into 215 forests. Of this 377,000 acres are already planted, including 68,000 acquired plantations, and 241,000 acres await planting, 340,200 acres are classified as unplantable, and the balance is agricultural land, forest workers' holdings, and nurseries (1,000 acres).

During the year 50,952 acres were acquired, of which 42,295 acres are plantable, 20,096 acres were planted, 4,186 acres thinned, and 633 acres filled. Thirty-one forest workers' holdings were established, making the total 1,299.

Reference is made to the steps taken to improve management in private woodlands. In order to increase the supply of foremen foresters, five special courses of instruction extending over three months each were arranged, three in England and two in Scotland. A conference on Private Forestry was held in February 1938. It was agreed that the first step was the enlightenment of the woodland owner and the public on the whole question of forestry, and it was recommended that an advisory service on an experimental basis should be established in England and Wales.

The Argyll National Forest Park was opened by the Chairman of the Forestry

Commissioners on 1 May 1937. During the year 20,000 'night accommodations' were provided in the park.

The forest year 1937 was not a serious one for fire. The area burnt, 126 acres, and the damage, £2,140, were the lowest in recent years. Railways continue to be the principal cause of forest fires, 48 per cent.

The only new departure in research work was the formation of special nurseries for the raising of poplars.

The total expenditure was £948,262, and receipts totalled £252,292, both showing advances over those of the previous year.

Report on the Demand for Timber in Shipbuilding and in Docks and Harbours. Forestry Commission Utilization Series, No. 4. H.M. Stationery Office, London, 1938. Price 1*s.* 3*d.*

THIS publication, like its predecessors in the same series, contains much interesting matter and several attractive illustrations. The kinds and quantities of timber used in the construction of a large range of ships from battleships and large liners to fishing craft are given. In spite of the use of steel, large quantities of timber are used in and about shipyards and docks. The proportion of home-grown timber used at present is small and little goes into the actual construction of the larger ships, being used mainly for the maintenance of shipyard plant. Much of the timber required, such as teak, Borneo white, and other tropical timbers, cannot be produced in this country, but when available there is a considerable market in shipyards and dock undertakings for spruce and pine for constructional work and for railway sleepers, &c. Particularly for the smaller craft, oak is used extensively, and the demand for 'crooks' far exceeds the supply. There is also a good demand for larch planks, but a frequent complaint is the presence of small dead knots that fall out. Early brashing would be a remedy. There is also a demand for larch thwart knees.

Those concerned are to be congratulated on this publication.

Report of the Forest Products Research Board for the Year 1937. H.M. Stationery Office, London. Price 2*s.*

AS usual, the report provides a useful summary of the progress of research in the numerous sections of the laboratory, as well as dealing with its other activities, educational and advisory. All members of the Society will find this report both interesting and instructive.

Reference is made to the work on tension wood in beech, published in *Forestry*, xi, and to work on gelatinous fibres. The study on cell-walls has shown that tropical hardwoods are more strongly lignified than temperate hardwoods, and this is correlated with the fact that the former are generally stronger in compression parallel to the grain, but weaker in impact bending and in toughness. It is intended to summarize available information on the differences between sapwood and heartwood.

There is an extensive report on the work done on the moisture relations of wood, and on kiln-seasoning. Wood bending tests on ash showed that light, fast-grown material, about five annual rings per inch, taken from the butt was best. Pin knots affected its bending qualities adversely.

The progress being made in woodworking research is recorded, and there are a number of interesting illustrations.

Railway sleepers laid down in 1935 were inspected for splitting. It was found that

incising decreased splitting, and that home Scots pine, and still more so home Douglas fir, showed less splitting than Baltic redwood.

The study of the relation between starch depletion and *Lyctus* attack has been one of the principal activities of the Entomology Section. This work is being described in the current volume of *Forestry*. Work has been continued on the factors affecting the development of the Death-watch beetle; and a visit was paid to Germany and Denmark in connexion with attacks of the House Longhorn beetle, *Hylotrupes bajulus*.

The staff of the Mycology Section has spent a considerable amount of time on the preparation of a bulletin on 'The Principal Decays of Softwoods used in Great Britain', which is now in the press. This should be a very useful publication. The tests on the natural durability of timber were continued on a number of colonial and home-grown species. Turkey oak was found to be much less resistant to decay than English oak.

The work in the Wood Chemistry Section is described, including the effect of bleaching by hydrogen peroxide.

The call for advisory work has increased substantially in all sections.

Commercial Mahoganies and Allied Timbers. By B. J. Rendle. Forest Products Research Bulletin, No. 18. H.M. Stationery Office, 1938. Price 2*s*.

THIS bulletin gives an excellent summary of information on the distribution, supplies, and wood characters of these timbers. The term True Mahogany is applied to *Swietenia* spp. from the West Indies and Central America from Southern Florida to Brazil. Spanish mahogany, *S. mahogoni*, has held an important place amongst cabinet timbers since it was introduced into this country 200 years ago until recent times. Then the African timbers allied to *Swietenia* are dealt with. African mahogany, *Khaya* spp., are considered to be the most suitable substitute for true mahogany, alike in its properties and because of abundant supplies. *Khaya* spp. are widely distributed in tropical Africa, both east and west. *K. ivorensis* from West Africa is the principal source of commercial supplies at present. Quality varies from district to district. Then follows a section on *Entandrophragma* spp. from West and Central Africa. The timber is known as Sapele wood or Sapele mahogany. Other timbers dealt with are Gaurea (*Gaurea* spp.), Crabwood (*Carapa* spp.), *Cedrella* spp., African walnut (*Lovea klaineana*), avodiné (*Turraeanthus africana*), and Gaboon mahogany (*Aucoumea klaineana*; now of great importance in the plywood industry).

There are ten plates illustrating the different timbers.

Dry Rot in Wood. By K. St. G. Cartwright and W. P. K. Findlay. Forest Products Research Bulletin, No. 1. Third Edition. H.M. Stationery Office, London, 1938. Price 1*s*.

THE demand for this bulletin has been so great that a third edition has been called for. The opportunity has been taken to include further research on the subject, and to increase the number of illustrations. It gives a concise but comprehensive account of the fungi causing dry rot, its detection and practical treatment, and methods of prevention.

Recent Work on the Moisture in Wood in Relation to Strength and Shrinkage. By W. W. Barkas. Forest Products Research Special Report, No. 4. H.M. Stationery Office, London, 1938. Price 9*d*.

THIS is a scientific report on the work of the Physics Section of the Laboratory on this difficult subject. As the results of this research, the author postulates a new theory of shrinkage in place of that which implied a fibre saturation point controlled

by the cell-wall water removed or added. He differentiates between the molecular and capillary water held in the cell-wall, and states that the water in the cell cavities cannot be sharply differentiated from the capillary water in the cell-wall. His experiments show that the amounts of water held by both these types of water in the cell-wall vary with the relative humidity, and that at any given humidity each type shows a larger sorption on drying than on wetting. A conclusion of importance is that wood reacts identically under externally applied loads and under internal shrinkage forces.

Forest Products Research Records. H.M. Stationery Office, London, 1938.

No. 24. *African Pencil Cedar.*

No. 25. *Machinery and Equipment used for Bending Wood.*

No. 26. *Kiln-drying Schedules.*

NO. 24 deals with *Juniperus procera*, a well-known forest tree in East Africa. It is a source of pencil slats, but its defect compared with *J. virginiana* is that it is harder and more difficult to whittle and also more liable to warp. A method of softening is described to improve the first defect. The warping is due principally to a high incidence of compression wood, and air conditioning in the pencil factories would likely reduce warping due to the effect of moisture changes in this compression wood.

No. 25 describes and illustrates various methods and equipment used for bending wood by means of power-driven machinery.

No. 26 gives useful information on kiln-drying practice including a short account of the factors influencing the choice of temperatures and humidities, the effect of these factors on kiln-drying properties, and the application of different kiln-drying schedules to 178 timbers.

Forest Bibliography to 31st December, 1933. Part III. Department of Forestry, University of Oxford, 1938. Price 12*s.* 6*d.*

PART III of this excellent bibliography deals with Forest Protection. It is subdivided into: (1) Man, demarcation and offences; (2) Animals, including bird and game preservation; (3) Atmospheric influences, frost, insolation, wind, hail, and snow; (4) Fire; (5) Weeds, including climbers, &c.; (6) Other agencies, including floods, shifting sands, reclamation works, drainage, &c.; and (7) Fencing. The library of the department is rich in forestry periodicals, including the early issues of the principal German journals, hence the bibliography is unusually complete.

The Black Poplars. By G. S. Cansdale and others. Imperial Forestry Institute, Oxford. Price 3*s.* 6*d.*

THIS small book should be of considerable use in differentiating members of this confusing group of trees. Uncertainty regarding different species and varieties and their utility has been one impediment to more extensive planting of poplar in this country, although success in poplar cultivation is by no means easy to secure.

The characters important in identification are the translucent leaf-margin, ciliation on leaf-margin, glands at junction of the petiole and leaf-blade, and shape of petiole in cross-section. Attention is drawn to the existence of two leaf-types on long and short shoots respectively, hence to the importance of using corresponding types when comparing different trees. In hybrids the two different types may reflect a corresponding difference between the leaves of the two parent species.

Most space in the book is devoted to a description of the genus *Populus*, its division into five sections, and the specific descriptions of poplars of the section *Aigeiros*, the Black Poplars. In conclusion a key is provided for the species and hybrids of *Populus* indigenous to or commonly cultivated in Britain. There is one illustration showing the principal diagnostic characters used. Further illustrations to bring out the characters in the various species would have been useful.

A World Tour for the Study of Soil Erosion Control Methods. By A. Grasovsky. Imperial Forestry Institute Paper, No. 14, 1938. Price 5*s*.

THIS publication records in an interesting way, and with illustrations, an extensive itinerary made by Dr. Grasovsky, of the Palestine Forest Service, for the purpose of studying erosion problems and control measures. During 1936 and 1937 he travelled through Nigeria, the Sahara, Morocco, Algeria, across the United States of America, Japan, Java, Malaya, Ceylon, and India. About 1½ months was spent in West and North Africa, about 2 months in the U.S.A., mainly in the Middle-West and West, while the visits to the countries were of shorter duration. It is clear that the author saw much of value on his journeyings, and much useful data are recorded. In addition a selected bibliography for each region is given.

Pine Nutrition. By S. L. Kessell and T. N. Stoate. Western Australian Forest Dept. Bulletin, No. 50, 1938.

SOME 11,000 acres of pines, principally *P. radiata* and *P. pinaster* have been planted in Western Australia during the past 15 years, mostly on sites which previously carried *Eucalyptus* forest of low value. In most instances the plantations have developed normally, but a certain amount of trouble has arisen. In *P. radiata* these disorders include: rosetting, or marked reduction in the length and quantity of the needles, and reduction in length of branches; yellowing sometimes leading to 'dead top' or complete stagnation, or under better conditions to 'thin crown'; die-back; and needle fusion. In *P. pinaster* what is called 'short needle' sometimes occurs. This bulletin discusses these disorders, their cause, and remedy. It is of special interest to foresters in this country, because most of these types of subnormal growth are to be found on the poorer soil types in this country, e.g. peats and upland heaths. It is known now, both in Australia and in South Africa, that *P. radiata* is a relatively exacting species. The particular factor with which correlation has been got with growth in Western Australia is the P_2O_5 content of the soil. When it is 0·04 per cent. or over, *P. radiata* develops normally, the corresponding figure for *P. pinaster* being 0·015 per cent. This is suggested as an indicator figure only, and not that the phosphorus content is necessarily the limiting factor. The P_2O_5 content, however, ceases to be a useful factor for areas previously cultivated. Various other factors such as soil moisture, clearing methods, nitrogen supply, and mycorrhora relations have been investigated, but no correlations with the growth of the pines could be demonstrated. The remedial measures which have been beneficial are manuring with superphosphate, generally at the rate of 1 cwt. per acre, and ploughing before planting. These also have been the methods which have given results in this country on poor heath soils except that basic slag is generally used. In Western Australia, however, the most spectacular results have been got by spraying the plants in check with a zinc salt, generally zinc sulphate. Relatively small quantities of dilute solutions, e.g. 1¼ or 2½ per cent. rapidly produce healthy growth on the most abnormal pines.

International Yearbook of Forestry Statistics, 1933–5. Vol. II. *America.* Rome, 1938.

IN 1936 volume i which gave information for Europe and the U.S.S.R. appeared. The present volume deals with North, Central, and South America, and gives much useful statistical data both for the forests and the trade in wood in the countries of America. These have been compiled mainly from official sources, and attention is directed to the gaps in available information, and to the confusion in units and methods of measurement. In spite of these defects this volume will constitute a useful source of reference.

Kolonialforstliche Mitteilungen. Band 1, Heft 1, Mai, 1938. J. Neumann, Neudamm-Berlin.

THIS new German periodical, issued from the Institute for Foreign and Colonial Forestry at Tharandt under the editorship of the indefatigable Professor Heske is part of the preparations for the return of Germany's former colonies. The different articles in this volume deal mainly with Africa, and particularly the Cameroons. They describe the general conditions of climate, geology, soil, forest types, timbers, &c., and are well illustrated. There are some particularly good photographs of forest conditions in what is called German East Africa, in an article by Professor Tobler entitled 'An Introduction to the Biology of Tropical Forests'.

Useful Trees and Shrubs. By F. B. Robinson. Gerrard Press, Champaign, Illinois. Price 4.50 dollars.

THIS is a somewhat unusual publication. It consists of a set of cards on which are recorded information about 500 trees and shrubs hardy in northern U.S.A. and Canada, and in common use for ornamental purposes. The cards are of different colours, white for deciduous trees, green for conifers, &c. The information listed includes the native habitat, form, colour, time of flowering, fruiting, pests, tolerance to pruning, and aesthetic value. There are spaces for sketches of the winter and summer forms of the shrubs and trees.

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